(4)

N-1789

NCEL
Technical Note

November 1988

By M. Jacoby

Sponsored by Marine Corps Research, Development and Acquisition Command

PRESSURE COEFFICIENTS FOR BASIC TENSIONED-MEMBRANE STRUCTURE FORMS

ABSTRACT This report details FY85 wind tunnel tests on basic tensioned-membrane structure forms, data reduction and analysis, and results. Models of parallel and diagonally-arched structures were tested. Testing was performed at the James Forestal Laboratory wind tunnel, Princeton University, and the environment wind tunnel located at the Naval Civil Engineering Laboratory (NCEL). All data and results have been converted to pressure coefficient form to facilitate their use in wind load calculations. Results are presented in Appendixes A, B, and C. Appendixes A and B give average and peak section pressure coefficients arranged by model for different wind incident angles, respectively. Appendix C shows pressure coefficient contour plots arranged by model for different wind incident angles. The effects of varying length, height, wind incident angle, and cross section on parallel-arched structures were measured. Finally, an example wind load calculation using the results is contained in Appendix D.

NAVAL CIVIL ENGINEERING LABORATORY PORT HUENEME CALIFORNIA 93043

METRIC CONVERSION FACTORS

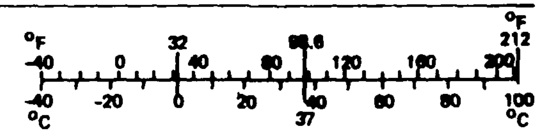
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2,000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1,000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1 REPORT NUMBER TN-1789	2 GOVT ACCESSION NO. DN666386	3 RECIPIENT'S CATALOG NUMBER
4 TITLE (and Subtitle) PRESSURE COEFFICIENTS FOR BASIC TENSIONED-MEMBRANE STRUCTURE FORMS		5 TYPE OF REPORT & PERIOD COVERED Not Final; FY86 6 PERFORMING ORG. REPORT NUMBER
7 AUTHOR(s) M. Jacoby		8 CONTRACT OR GRANT NUMBER(s)
9 PERFORMING ORGANIZATION NAME AND ADDRESS NAVAL CIVIL ENGINEERING LABORATORY Port Hueneme, California 93043-5003		10 PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS C0078E-4-101
11 CONTROLLING OFFICE NAME AND ADDRESS Marine Corps Development and Education Command Quantico, VA 02134		12 REPORT DATE November 1988 13 NUMBER OF PAGES 90
14 MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15 SECURITY CLASS (of this report) Unclassified 15a DECLASSIFICATION DOWNGRADING SCHEDULE

16 DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution is unlimited.

17 DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18 SUPPLEMENTARY NOTES

19 KEY WORDS (Continue on reverse side if necessary and identify by block number)

Wind tunnel, tensioned-membrane structure, pressure coefficients . (JES)

20 ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report details FY85 wind tunnel tests on basic tensioned-membrane structure forms, data reduction and analysis, and results. Models of parallel and diagonally-arched structures were tested. Testing was performed at the James A. Forestal Laboratory wind tunnel, Princeton University, and the environment wind tunnel located at the Naval Civil Engineering Laboratory (NCEL). All data and results have been converted to pressure coefficient form to facilitate their use in wind load calculations. Results are presented

Continued

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

20. Continued

in Appendixes A, B, and C. Appendixes A and B give average and peak section pressure coefficients arranged by model for different wind incident angles, respectively. Appendix C shows pressure coefficient contour plots arranged by model for different wind incident angles. The effects of varying length, height, wind incident angle, and cross section on parallel-arched structures were measured. Finally, an example wind load calculation using the results is contained in Appendix D.

Library Card

Naval Civil Engineering Laboratory
PRESSURE COEFFICIENTS FOR BASIC TENSIONED-MEMBRANE STRUCTURE FORMS (Not Final) by M. Jacoby
TN-1789 90 pp illus Nov 1988 Unclassified

1. Wind tunnel 2. Tensioned-Membrane I. C0078E-4-101

This report details FY85 wind tunnel tests on basic tensioned-membrane structure forms, data reduction and analysis, and results. Models of parallel and diagonally-arched structures were tested. Testing was performed at the James A. Forestal Laboratory wind tunnel, Princeton University, and the environment wind tunnel located at the Naval Civil Engineering Laboratory (NCEL). All data and results have been converted to pressure coefficient form to facilitate their use in wind load calculations. Results are presented in Appendixes A, B, and C. Appendixes A and B give average and peak section pressure coefficients arranged by model for different wind incident angles, respectively. Appendix C shows pressure coefficient contour plots arranged by model for different wind incident angles. The effects of varying length, height, wind incident angle, and cross section on parallel-arched structures were measured. Finally, an example wind load calculation using the results is contained in Appendix D.

CONTENTS

INTRODUCTION

The Naval Civil Engineering Laboratory (NCEL) has been tasked by the Marine Corps to develop an expeditionary shelter system. This system will provide environmental protection for command and control, equipment maintenance and storage, and other combat support functions. The system being developed utilizes tensioned-membrane technology. Examples of tensioned-membrane structures are shown in Figures 1 and 2. This shelter system must withstand wind gusts up to 120 mph. For conventional buildings, standard guidelines such as NAVFAC DM-2.2 or ANSI A58.1-1982 (Ref 1 and 2) can be used to estimate wind loads. However, these guidelines cannot be used on tensioned-membrane structures due to their unusual construction. Section 6.4.3 of Reference 2 states that wind tunnel testing is "recommended for those buildings or structures having unusual geometric shapes, response characteristics, or site locations for which channeling effects or buffeting in the wake of upwind obstructions warrant special consideration, and for which no reliable documentation pertaining to wind effects is available in the literature."

FY84 development efforts included wind tunnel testing and compilation of data for various geometries and sizes of basic tensioned-membrane structure forms under consideration. The wind tunnel tests were performed by Ocean Structures, Inc., under contract to NCEL. Unreduced data from these tests were turned over to NCEL for reduction and analysis. This report documents these tests, FY85 verification wind tunnel testing performed by NCEL, analysis results, and conclusions.

BACKGROUND THEORY

This section details the basic equations and principles used for building aerodynamics and wind tunnel testing.

The pressure distribution around a body immersed in a moving fluid is primarily function of the local variation in fluid velocity produced by the body. ~~From~~ Bernoulli's equation, with the subscript o referring to freestream conditions,

$$\frac{p_o}{\rho_o} + g\, z_o + \frac{1}{2} v_o^{\,2} = \frac{p}{\rho} + g\, z + \frac{1}{2} v^2 \qquad (1)$$

where p = static fluid pressure
ρ = fluid mass density
g = acceleration of gravity
z = elevation
v = fluid velocity

For the low velocities encountered in building aerodynamics, compressibility effects are neglible. Assuming constant elevation, Equation 1 reduces to,

$$p - p_o = \frac{1}{2} \rho_o (v_o^2 - v^2) \tag{2}$$

the maximum pressure difference from this equation is,

$$(p - p_o)_{max} = \frac{1}{2} \rho_o v_o^2 \tag{3}$$

at the stagnation point where the flow velocity is zero. Dividing Equation 2 by this reference value, $(1/2) \rho_o v_o^2$, yields the following dimensionless form of Equation 2,

$$Cp = \frac{p - p_o}{\frac{1}{2} \rho_o v_o^2} = 1 - \left(\frac{v}{v_o}\right)^2 \tag{4}$$

where Cp is defined as the pressure coefficient. All data and results detailed here are in this form.

For wind tunnel testing of models, dynamic similitude conditions must be met. Dynamic similitude requires the Reynold's number for both the model and full size structure be the same, i.e.,

$$Re_{model} = Re_{prototype} \tag{5}$$

Strict adherence to Equation 5 is difficult when testing small-scale models. Generally, building forms are so angular that viscous effects are secondary. Reference 3 suggests that for wind tunnel testing of building forms, dynamic similitude will be met for model Reynold's numbers in excess of 11,000. As discussed later in this report, all model Reynold's numbers in this effort were between 170,000 and 950,000.

Finally, consideration must be given to accurately simulate full-scale boundary layer conditions. The distribution of mean windspeed with height is described by the power law relation,

$$\frac{\mu_z}{\mu} = \left(\frac{z}{\delta}\right)^a$$

where μ_z = wind speed at height z

μ = free stream wind speed

z = height

δ = boundary layer thickness

a = exponent, dependent on boundary layer type

Table 1 lists 1 different boundary layers and exponents.

Table 1. Boundary Layer Profiles and Power Law Exponents (Ref 4)

Boundary Layer Type	Power Law Exponent
City	0.34
Urban	0.18
Open terrain	0.17

Figure 3 shows these boundary layer profiles referenced to the NCEL wind tunnel. These boundary layers can be simulated in the wind tunnel by proper placement of flow impediments or screens upwind of the wind tunnel test section.

TEST DESCRIPTIONS

Two separate series of wind tunnel tests are described in this section. The first series was performed by Ocean Structures, Inc., under contract to NCEL. After receipt of this data, and compilation of data on similar structures from other sources, verification testing was performed at NCEL.

Wind tunnel testing performed under contract to NCEL was performed at the low turbulence wind tunnel located at the James Forestal Laboratory, Princeton University. Table 2 lists the wind tunnel characteristics.

Table 2. Princeton Wind Tunnel Characteristics

Characteristic	Specification
Working cross section	3 ft by 5 ft
Maximum speed	120 mph
Maximum blockage	5%

Blockage refers to the ratio of maximum cross-sectional area to test section cross-sectional area. Pressure measurements were made with pressure taps connected to a 90-tube manometer board using dyed alcohol with a specific gravity of 0.793. All pressure measurements were referenced to test section static pressure. Velocity measurements were made with a pitot-static tube connected to the manometer board. Figure 4 shows tube assignments.

Worst case environmental wind conditions are flow across open, flat terrain with few obstructions. Consequently, models were mounted away from test section walls to minimize boundary layer effects. Model mounting details are shown in Figure 5. The Reynold's number for all models varied between 570,000 and 950,000. Pressure taps were placed over roughly half of each model's surface. Each model was tested over wind incident angles from 0 to 180 degrees in 30-degree increments. Data were recorded by photographing the manometer board after the reading stabilized. Figure 6 shows a sample data photograph.

Dimensions of models tested at Princeton are shown in Figure 7. Models of both parallel- and diagonally-arched tensioned-membrane structures were tested. Model groups A, B, and C represent parallel-arched Clamshell Buildings, Inc., series 50 structures. Models in group A are of constant cross section and varying length. Models in groups B and C have constant lengths, but different cross sections (Figure 8). The diagonally-arched model tested was a 1/100-scale model of the Spandome, Inc., structure. All models were made of wood.

Another parallel-arched tensioned-membrane structure under consideration by NCEL was the Sprung Instant Structure, manufactured by Sprung Instant Structures, Inc. This structure is geometrically similar to the Clamshell structures mentioned above. Wind tunnel data on the Sprung was provided to NCEL by the manufacturer in FY84 (Ref 5). Preliminary analysis of wind tunnel data on both parallel-arched structures was conducted. Results showed much smaller negative pressures, or suctions, over the Sprung structure. Due to similarities between both parallel-arched structures, verification testing was performed at NCEL to rectify the differences. Characteristics of the NCEL wind tunnel are detailed in Table 3.

Table 3. NCEL Wind Tunnel Characteristics

Characteristic	Specification
Working cross section	3 ft by 5 ft
Maximum speed	45 mph
Maximum blockage	5 to 10%

Velocity measurements were made with a Kurtz hot-wire anemometer. Pressure measurements were made with pressure taps connected to a 47 channel Scanivalve Corp. valve tree and a Serta Systems 0 to 0.1 psid strain-gauge-type differential pressure transducer. All pressure measure ments were referenced to tunnel test section static pressure, measured at the model roof height. All instrumentation was controlled by a Macsym 2 microcomputer. Real-time conversion of pressure measurements to pressure coefficient form was also performed with this system.

Figure 9 shows dimensions of two of the three models tested. The parallel-arched models are 1/60 scale. The Sprung Instant Structures model shown in Figure 9 will hereafter be referred to as model D. The diagonally-arched 1/100-scale Spandome model used earlier at Princeton was also tested (Figure 7).

The atmospheric boundary layer for open, flat terrain with scattered windbreaks was simulated. Figure 3 shows the actual boundary layer profile during testing. Flow velocities during testing were approximately 8.2 meters per second, resulting in test Reynold's numbers of 170,000. For the parallel-arched models, one quarter section was tapped. Measurements were taken for azimuth angles varying over 180 degrees, in 30-degree increments. During each test run, corresponding to each azimuth angle, every tap was sampled 6,000 times. Data output consisted of average, maximum, and minimum pressure coefficients for each tap.

ANALYSIS

Comparisons of Princeton and NCEL wind tunnel data on the 1/100-scale diagonally-arched model were made. Results showed good correlation, with an average 3.7 percent difference between tap readings and a 26 percent standard deviation. Princeton test data were used for subsequent data analysis and reduction. Figure 10 shows comparisons of results on model D for NCEL, Reference 5 tests, and potential flow predictions. From the graphs, Reference 5 test data underestimated negative pressures, or suctions. As a result, NCEL data on the Sprung Instant Structure model were used for analysis and reduction.

Figure 11 shows the analysis and reduction flowchart. Each major step is discussed below. The first step in the data reduction process consisted of conversion of Princeton data to pressure coefficient form. Data from the Princeton tests were recorded by photographing the manometer board after the readings had stabilized (see Figure 6 for example). Columns 9 and 10 as identified in Figure 4, recorded the total tunnel and test section static pressures referenced to atmospheric, respectively. The total tunnel pressure is the sum of the dynamic pressure, and the static pressure,

$$p_H = p_S + \frac{1}{2} \rho v^2 \qquad (7)$$

where p_H = total tunnel pressure

p_S = static pressure

The dynamic pressure is determined by subtracting the test section static pressure from the total tunnel pressure:

$$\frac{1}{2} \rho v^2 = p_H - p_S \qquad (8)$$

This pressure difference can be calculated for the manometer board using,

$$p_H - p_s = S.G.\ \rho_{H_2O} (h_9 - h_{10}) \quad (9)$$

where S.G. = specific gravity of manometer fluid (0.793)

ρ_{H_2O} = density of water

h_9 = manometer fluid height in column 9

h_{10} = manometer fluid height in column 10

The pressure difference between the static pressure at tap x and test section static pressure is,

$$p_x - p_s = S.G.\ \rho_{H_2O} (h_x - h_{10}) \quad (10)$$

where h_x = manometer fluid height in column x.

At tap x, the pressure coefficient is calculated from,

$$Cp = \frac{h_x - h_{10}}{h_9 - h_{10}} \quad (11)$$

Using Equation 11, the pressure coefficients were calculated from the data photographs.

After data conversion to pressure coefficient form, pressure coefficient contour plots were generated. This was accomplished with the DISSPLA graphics software package from Issco, Inc., on the PRIME 750 minicomputer at NCEL. A geometric simulation of the wind tunnel models was constructed. Inputs were pressure tap coordinates and the correspondence pressure coefficients. Using a least squares weighting technique, contour plots were calculated in user defined intervals and superimposed on the model's surface. Appendix A contains top views of the computed contours, arranged by model and azimuth angle. These contours are approximations by nature of the weighting technique. An accuracy check revealed that the algorithm worked well in the interior of a surface, but had trouble accurately resolving contours along boundaries. This effect was compensated for by manually estimating pressure coefficient contours along model boundaries.

After contour plot generation, each model was sectioned, as shown in Figure 12. The parallel-arched models were divided up into 12 sections, symmetric about the model centerlines. The diagonally-arched model was divided into 16 sections. Section average pressure coefficients were calculated using,

$$\bar{C}p = \frac{\sum_i Cp_i A_i}{\sum_i A_i} \quad (12)$$

where $\bar{C}p$ = section average pressure coefficient

A_i = i^{th} area between contours

Cp_i = i^{th} pressure coefficient, equal to the average to the coefficients defining A_i

Areas were measured using a Salmoiraghi optical planimeter. Average section pressure coefficient results are found in Appendix B. Appendix C gives the largest negative or positive pressure coefficients for each section, arranged by model.

CONCLUSION

Results detailed in this report are based on rigid models. With tensioned-membrane structures, structural shape is fabric dependent. The dynamic behavior and total deformation of these structures in heavy winds is unknown. Should these deformations be excessive, the resultant flow about the structures will be altered, and the results presented may not be accurate. For diagonally-arched structures, fabric flutter may be a problem due to large expanses of unconstrained fabric. This represents another dynamic phenomenon not accounted for in the present work. Finally, application of results presented in this report is demonstrated in Appendix D.

ACKNOWLEDGMENT

The author would like to acknowledge Sophia K. Ashley of the Naval Civil Engineering Laboratory, for her experience, assistance, and support of the work described in this report.

REFERENCES

1. Naval Facilities Engineering Command. NAVFAV DM-2.2: Structural engineering design manual. Alexandria, VA, Oct 1970.

2. American National Standards Institute. ANSI A58.1-1982: American National Standard minimum design loads for buildings and other structures. New York, NY, Mar 1982.

3. Colorado State University. Wind engineering study of One Williams Center, Tulsa, by J.A. Paterka and J.E. Cermak. Fort Collins, CO, Dec 1974.

4. Naval Civil Engineering Laboratory. Technical Report R-912: Field and wind tunnel testing on natural ventilation cooling effects on three Navy buildings, by Sophia K. Ashley. Port Hueneme, CA, Dec 1984.

5. Babowal Builders and Engineers, Limited. Pressure distribution on a Sprung structure measured on a 1:96 scale model in the wind tunnel. Calgary, Canada, Jul 1981.

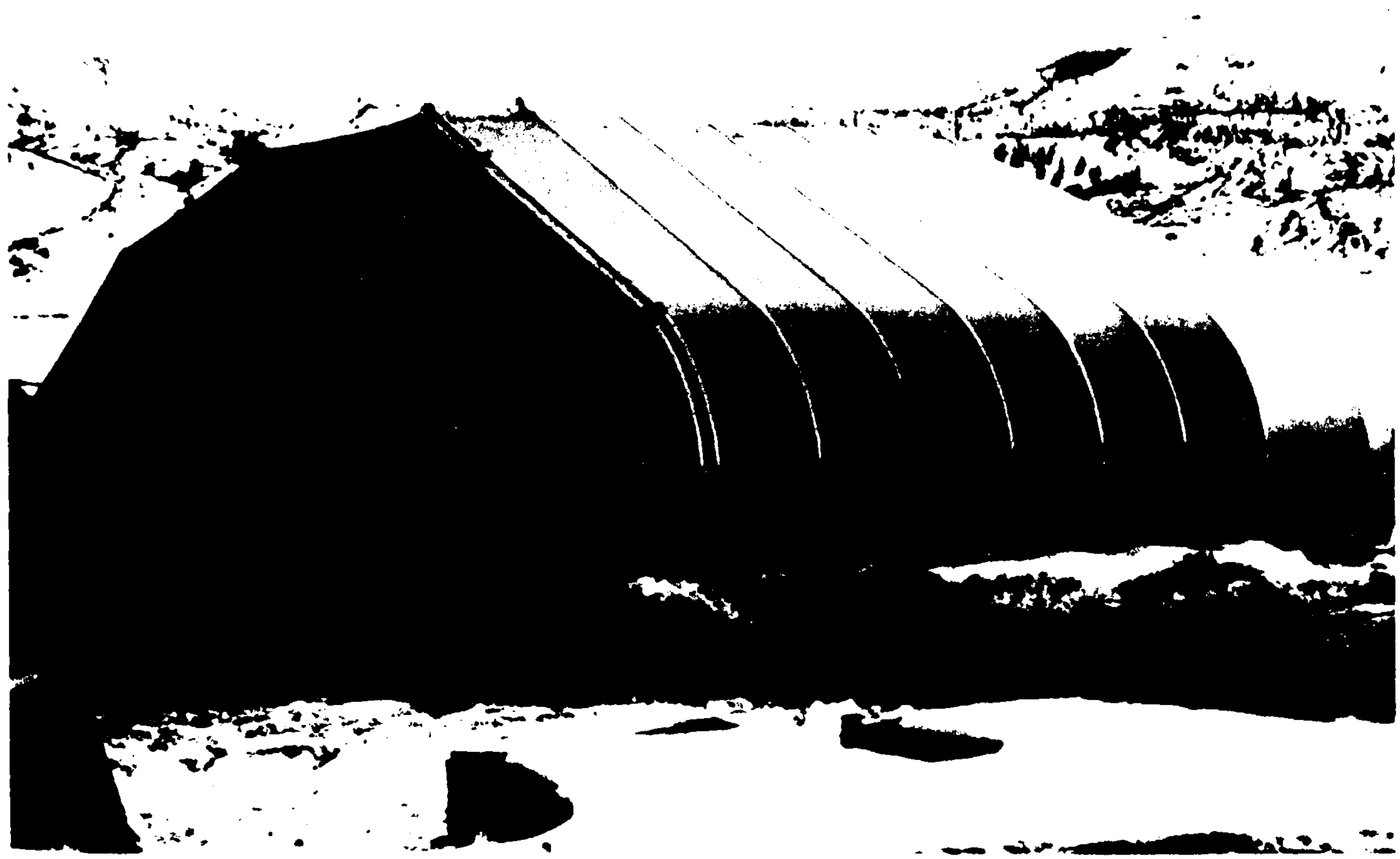


Figure 1. Example of parallel-arched tensioned-membrane structure.

Figure 2. Example of diagonally-arched tensioned-membrane structure.

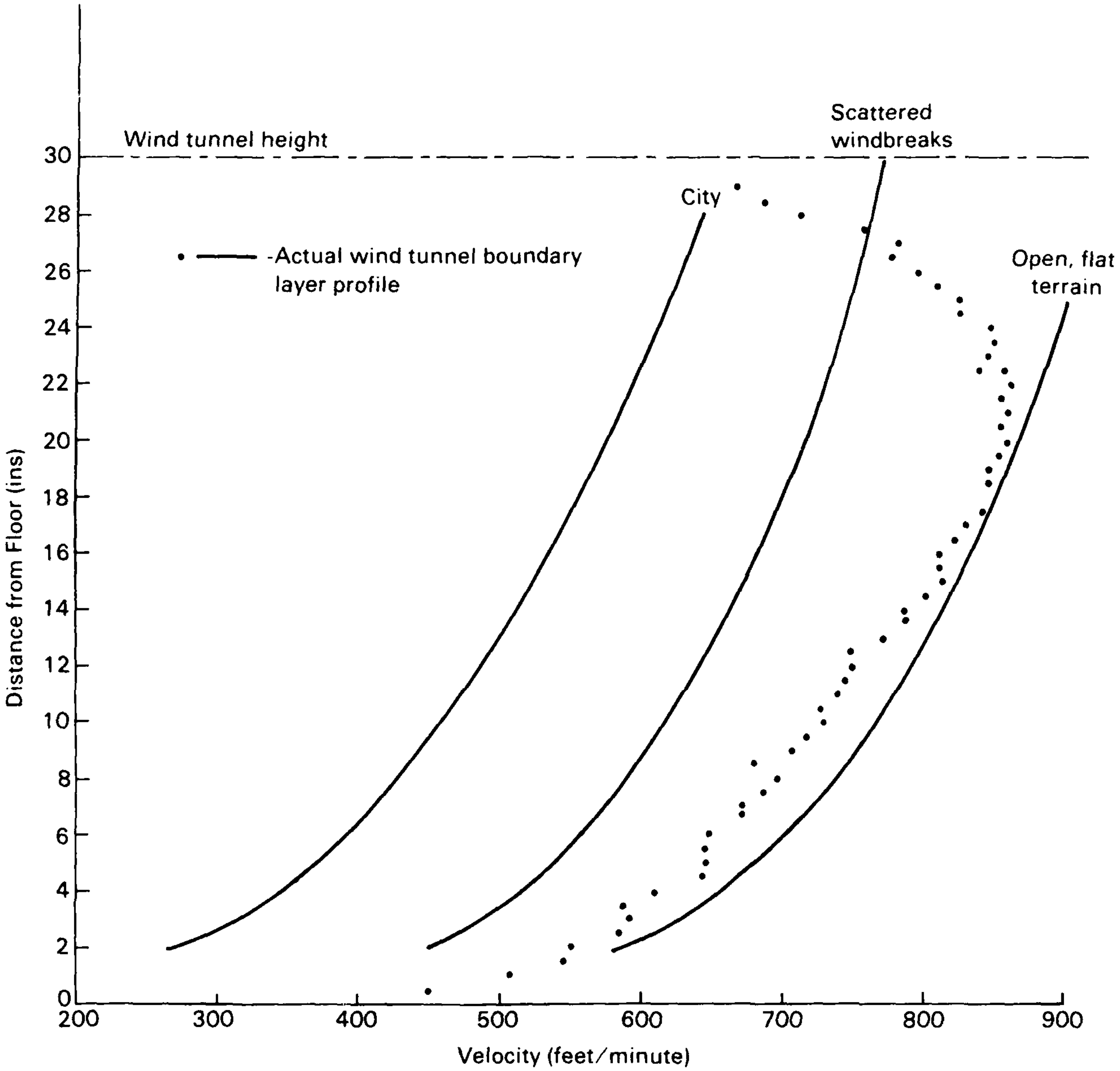


Figure 3. Atmospheric boundary layer profiles referenced to the NCEL wind tunnel.

MANOMETER BOARD 90 TUBE x 48" (Approx.) HEIGHT

DYED ALCOHOL SPECIFIC GRAVITY 0.793

1-6	-INTERNAL PRESSURES(OPEN MANIFOLD TUBES)
7,8	Groups ABC-ROOM AMBIENT PRESSURE
	Groups D&E-INTERNAL PRESSURE(OPEN MANIFOLD TUBES)
9	-TUNNEL TOTAL HEAD PRESSURE
10	-TUNNEL TEST SECTION STATIC PRESSURE
11-90	-MODEL STATIC TAPS, AS REQUIRED

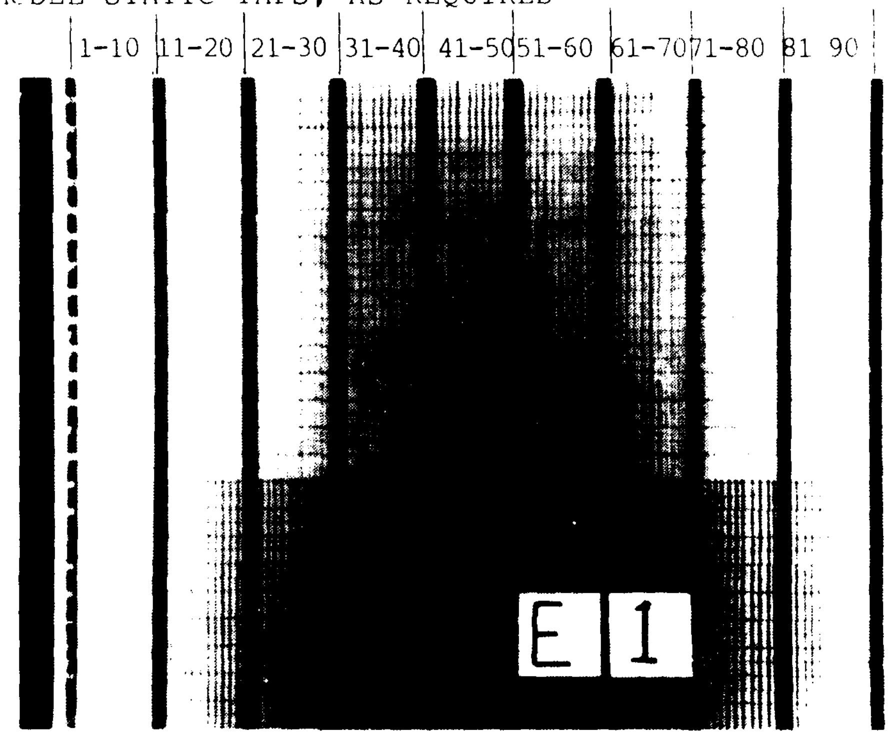


Figure 4. Manometer board tube assignments for Princeton wind tunnel testing.

Details of Princeton 3½′ x 5′ wind tunnel test section.

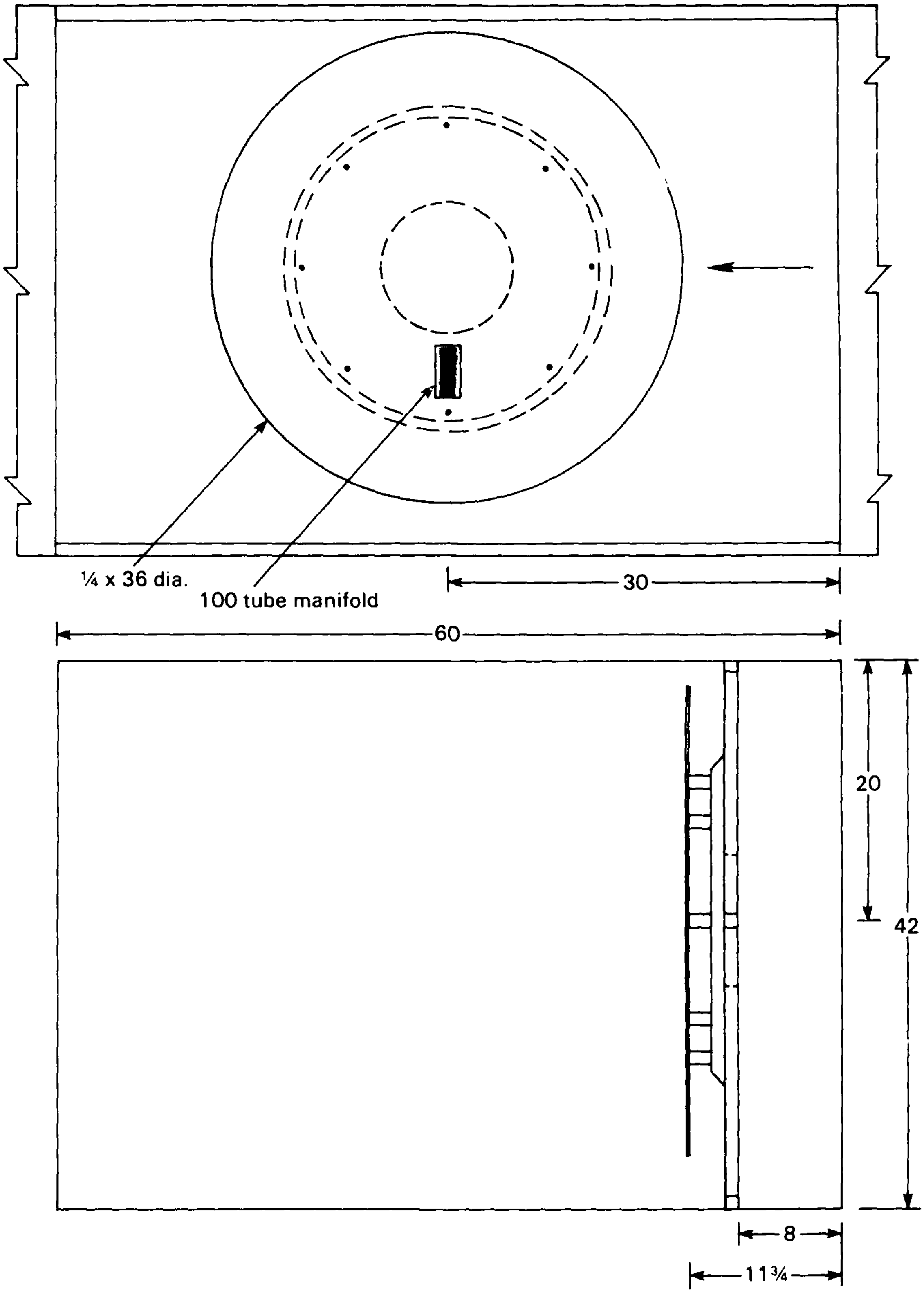


Figure 5. Princeton wind tunnel test section.

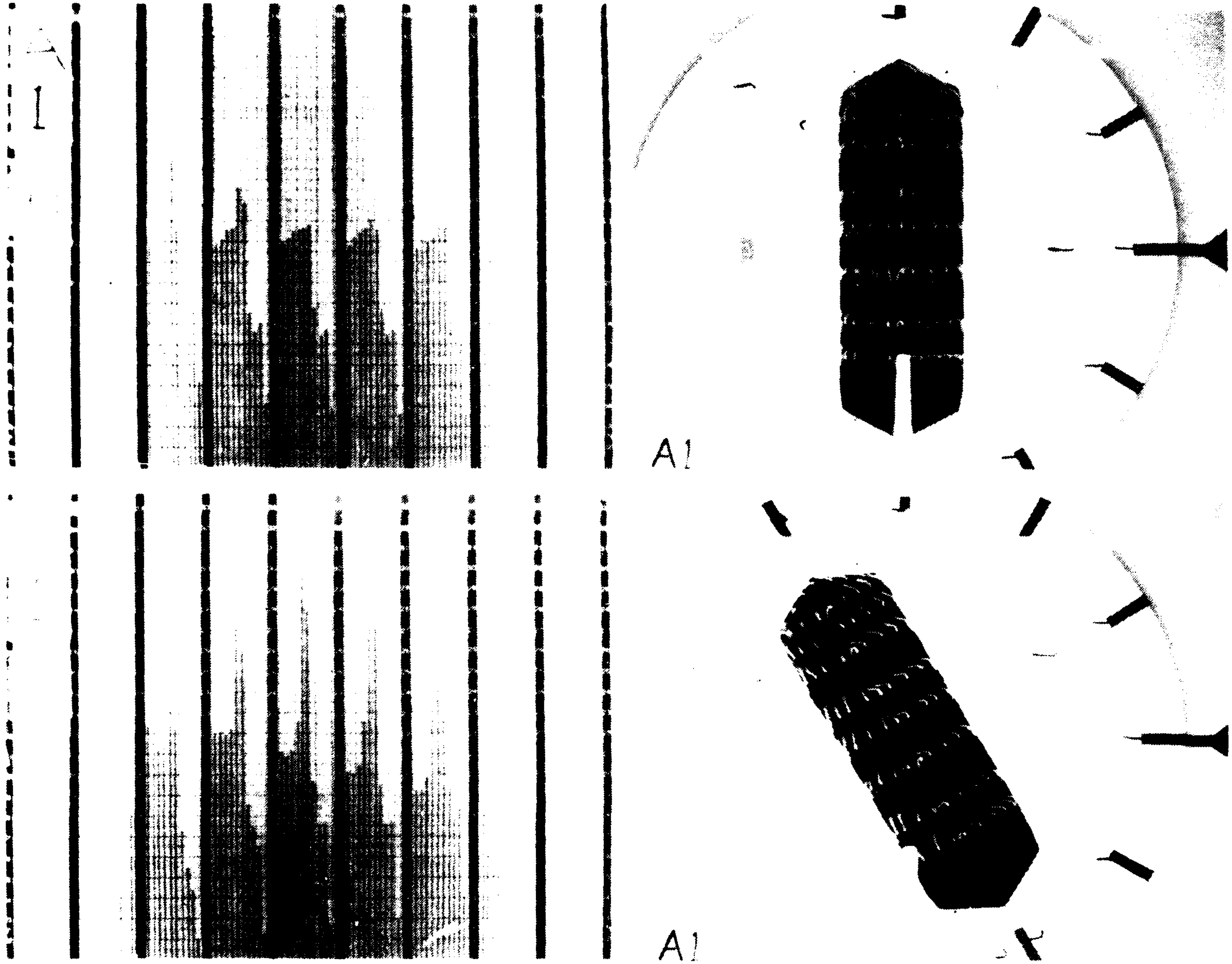


Figure 6. Sample of Princeton wind tunnel the data.

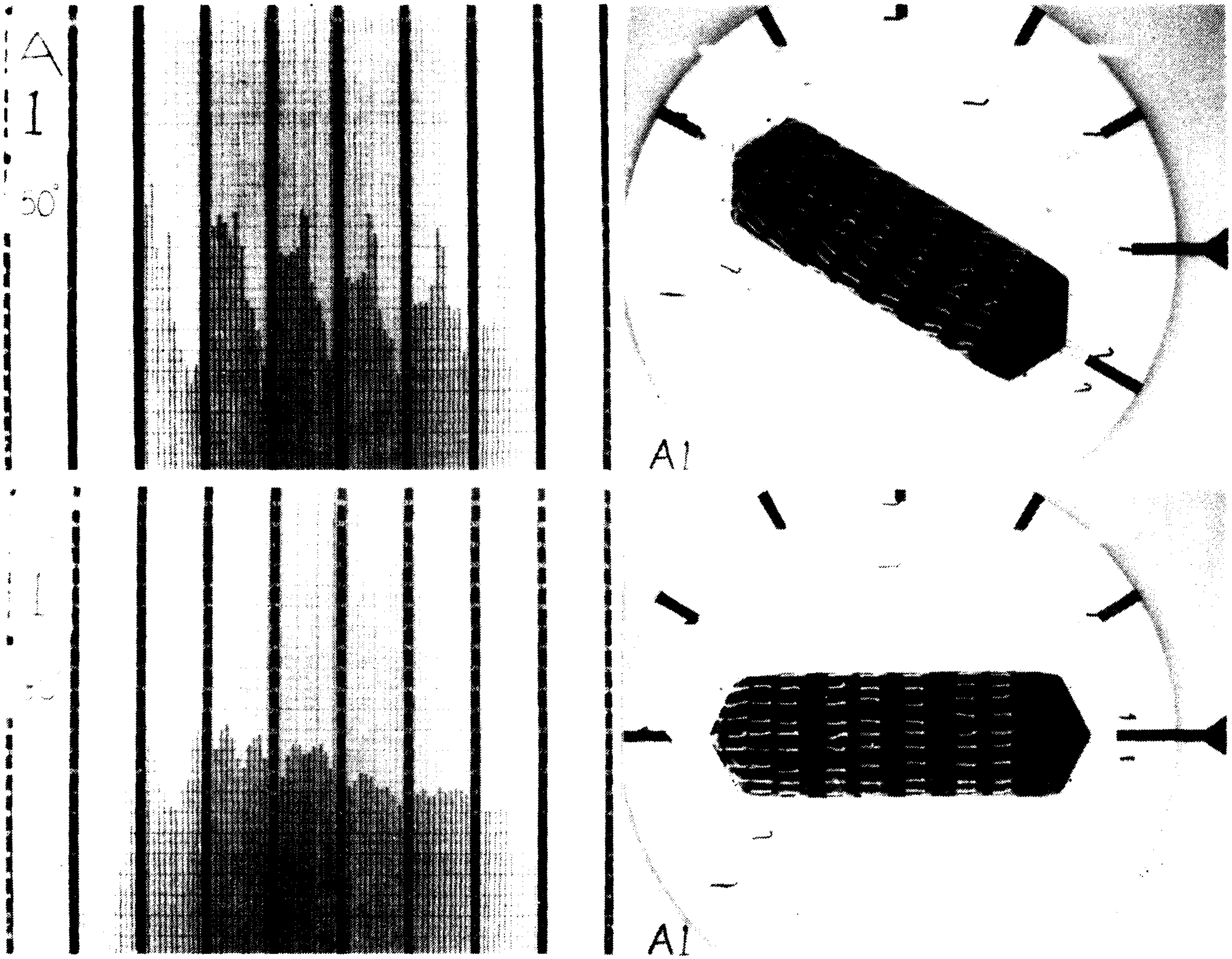
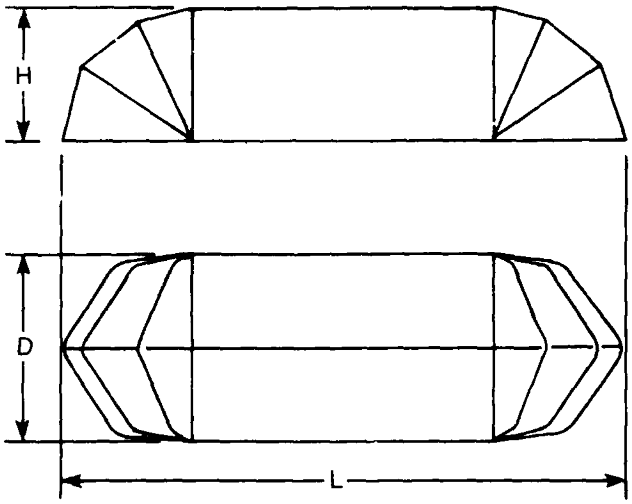


Figure 6. Continued.



Model	L *	D *	H *
A1	24.0	7.98	3.07
A3	18.0	7.98	3.07
A5	12.0	7.98	3.07
A6	9.0	7.98	3.07
B6	11.72	8.53	4.36
C6	14.30	9.08	5.65

* All dimensions in inches

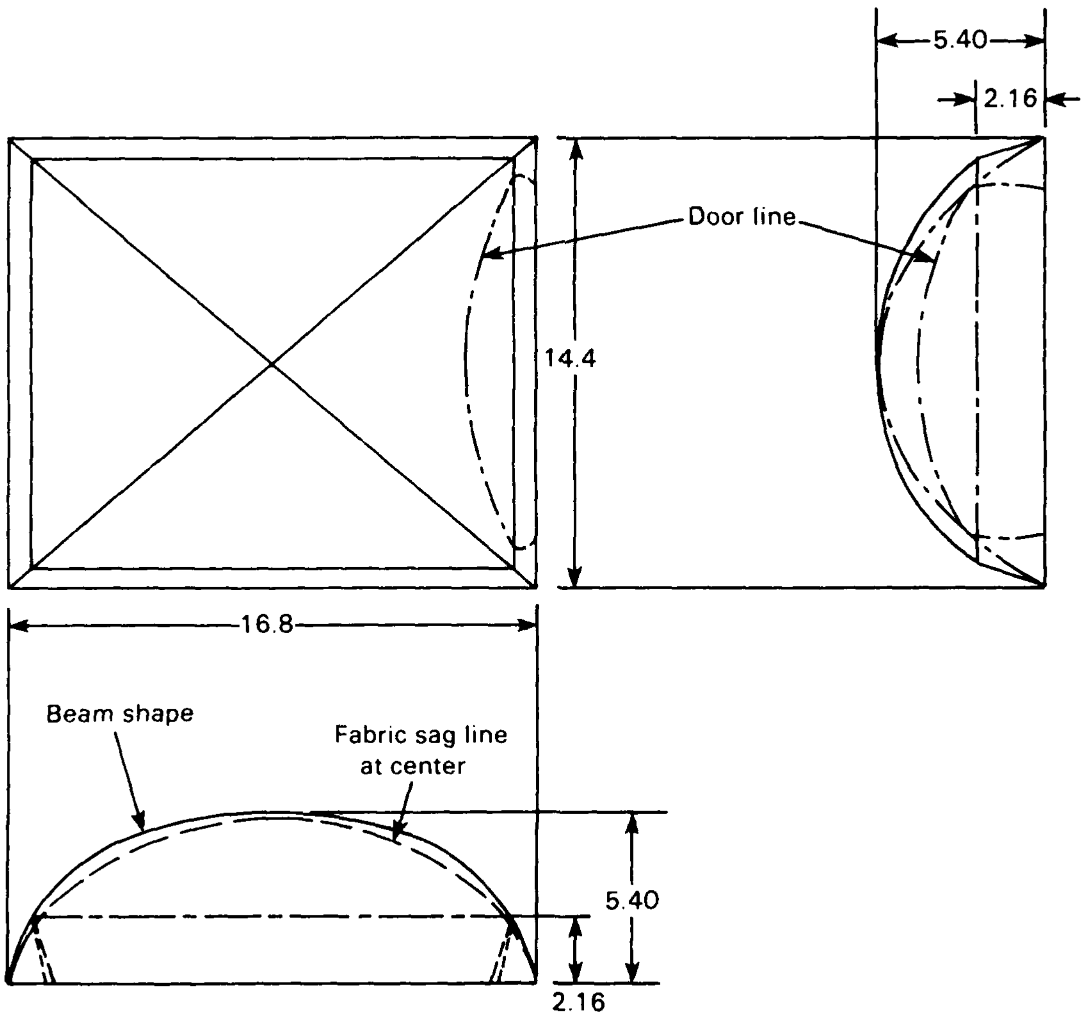
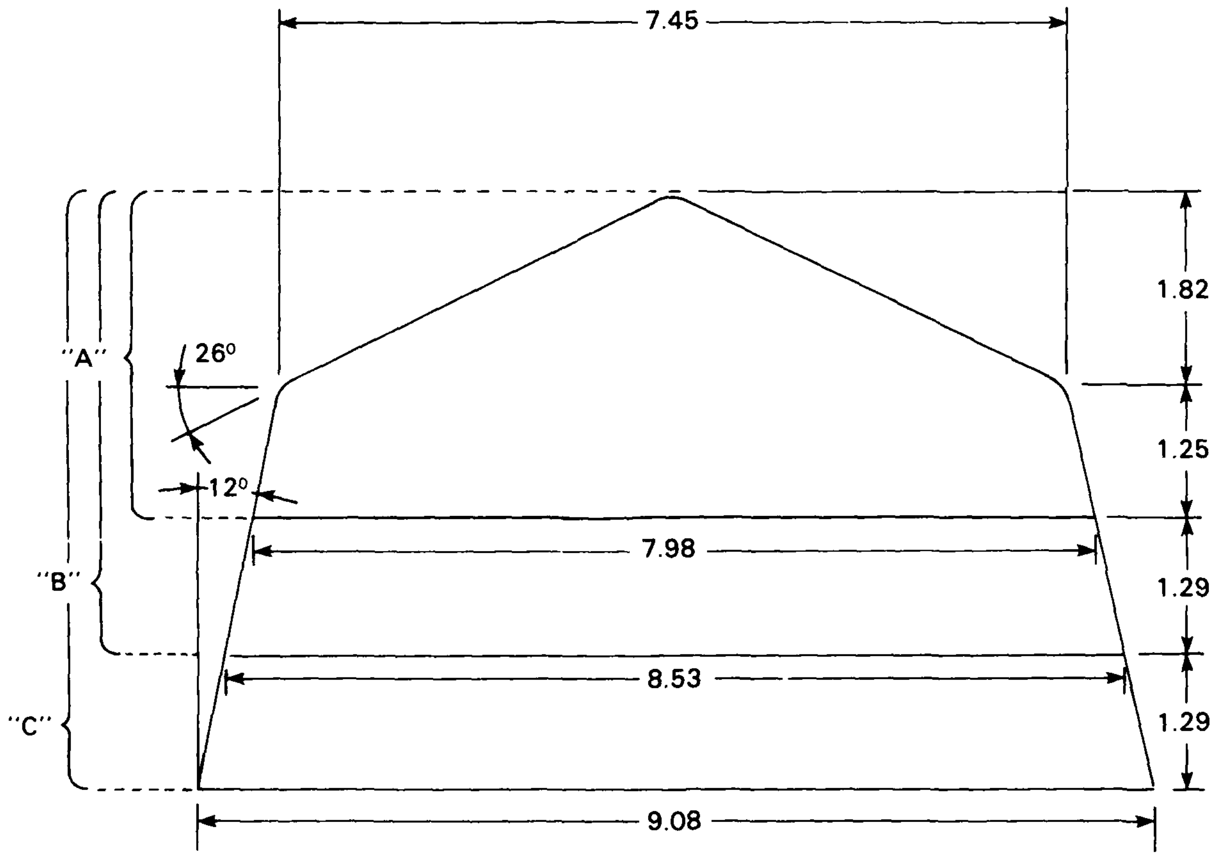


Figure 7. Dimensions of models tested at Princeton.



All dimensions in inches.

Figure 8. Cross-sections of model groups A, B, and C.

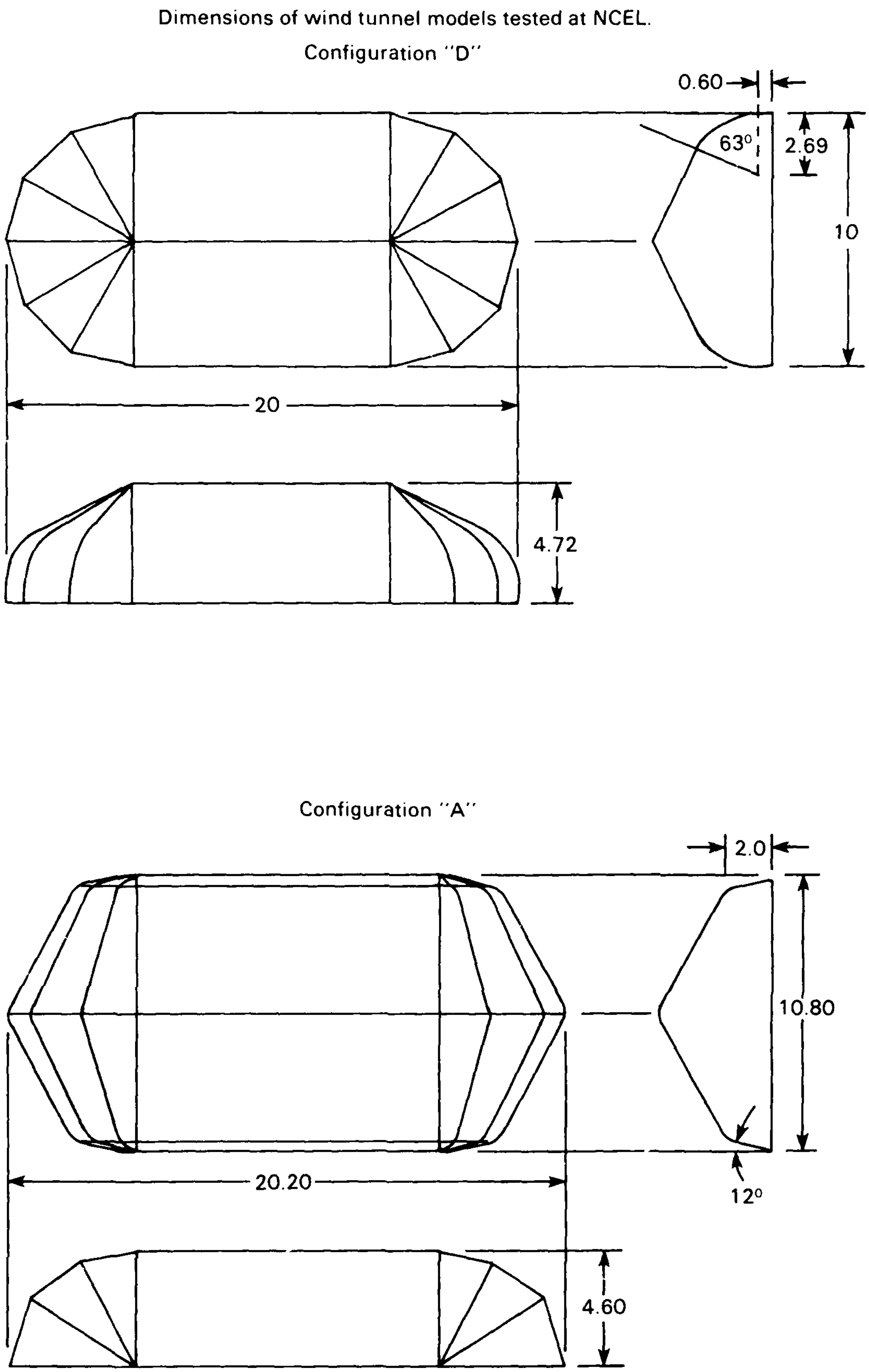
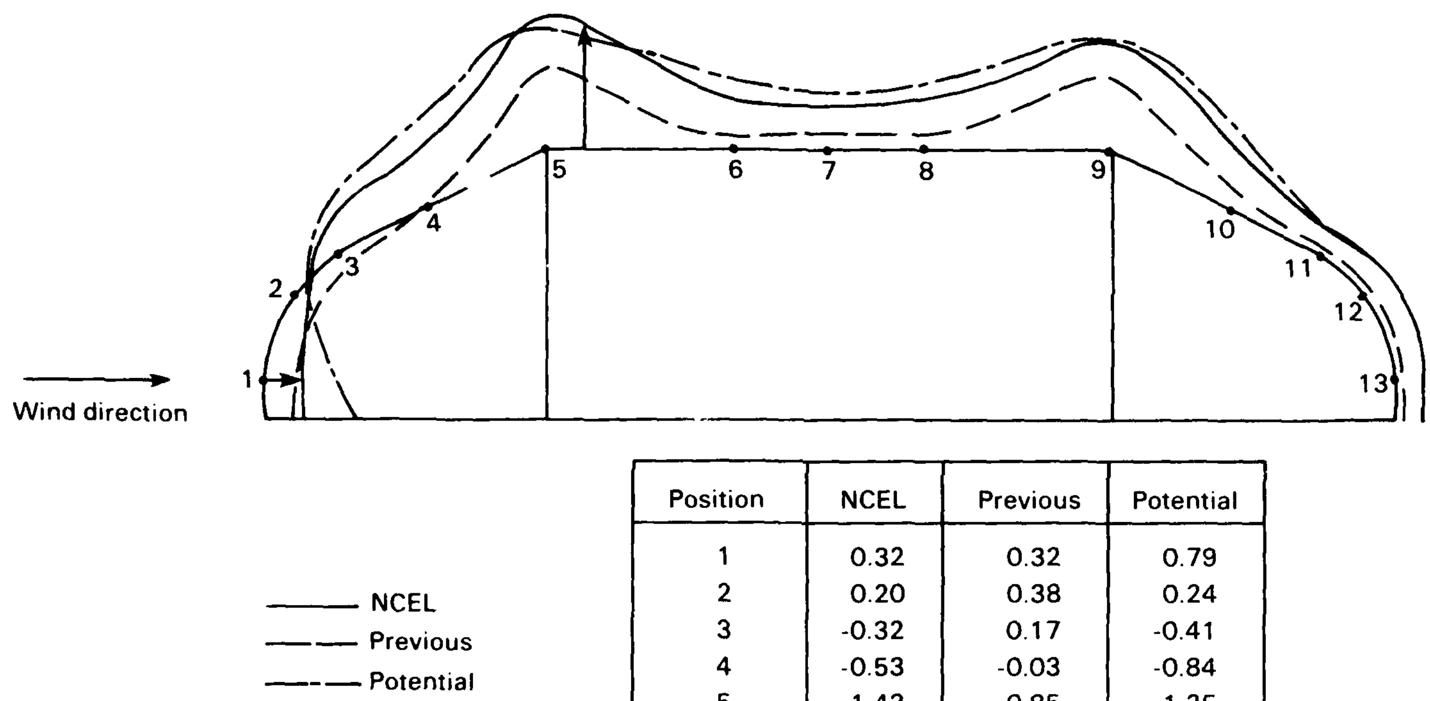


Figure 9. Models tested at NCEL.



Position	NCEL	Previous	Potential
1	0.32	0.32	0.79
2	0.20	0.38	0.24
3	-0.32	0.17	-0.41
4	-0.53	-0.03	-0.84
5	-1.43	-0.85	-1.25
6	-0.55	-0.17	-0.75
7	-0.50	-0.18	-0.60
8	-0.54	-0.18	-0.71
9	-1.12	-0.76	-1.18
10	-0.54	-0.19	-0.65
11	-0.30	-0.03	-0.24
12	-0.30	-0.03	—
13	-0.26	-0.03	—

All values refer to model centerline at 0° azimuth angle

Figure 10. Comparison of Configuration "D" wind tunnel tests.

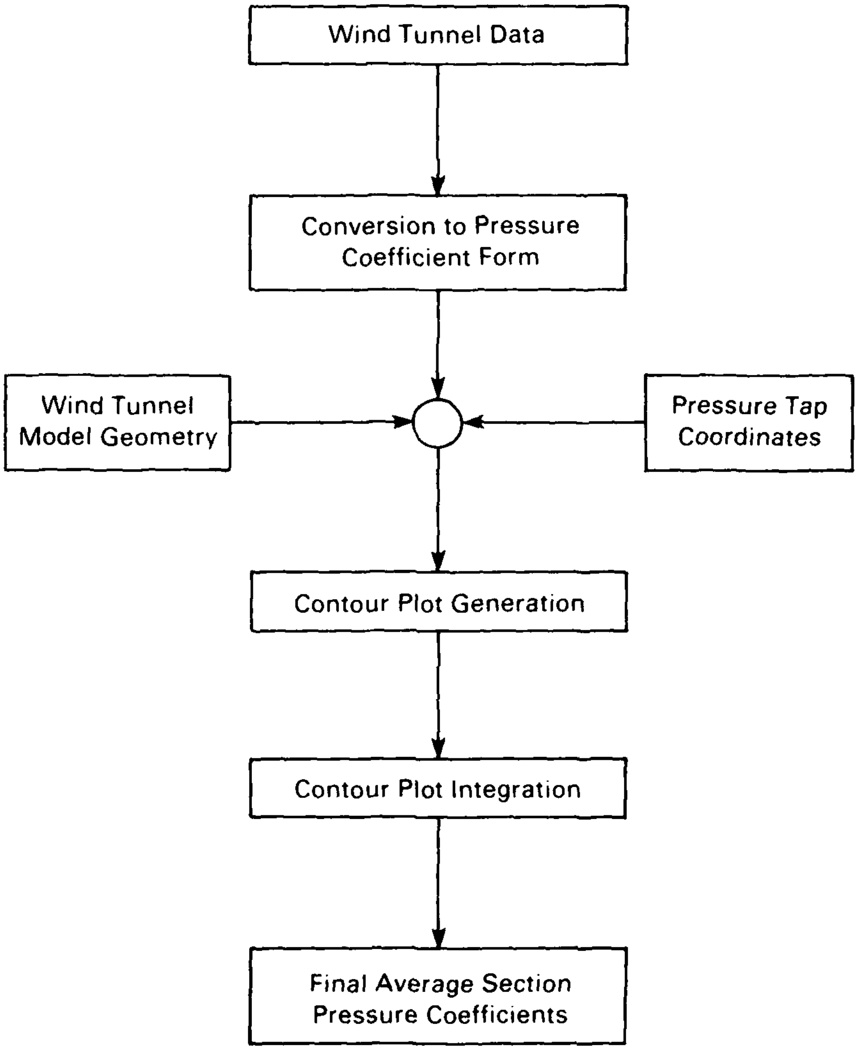


Figure 11. Data reduction and analysis flowchart.

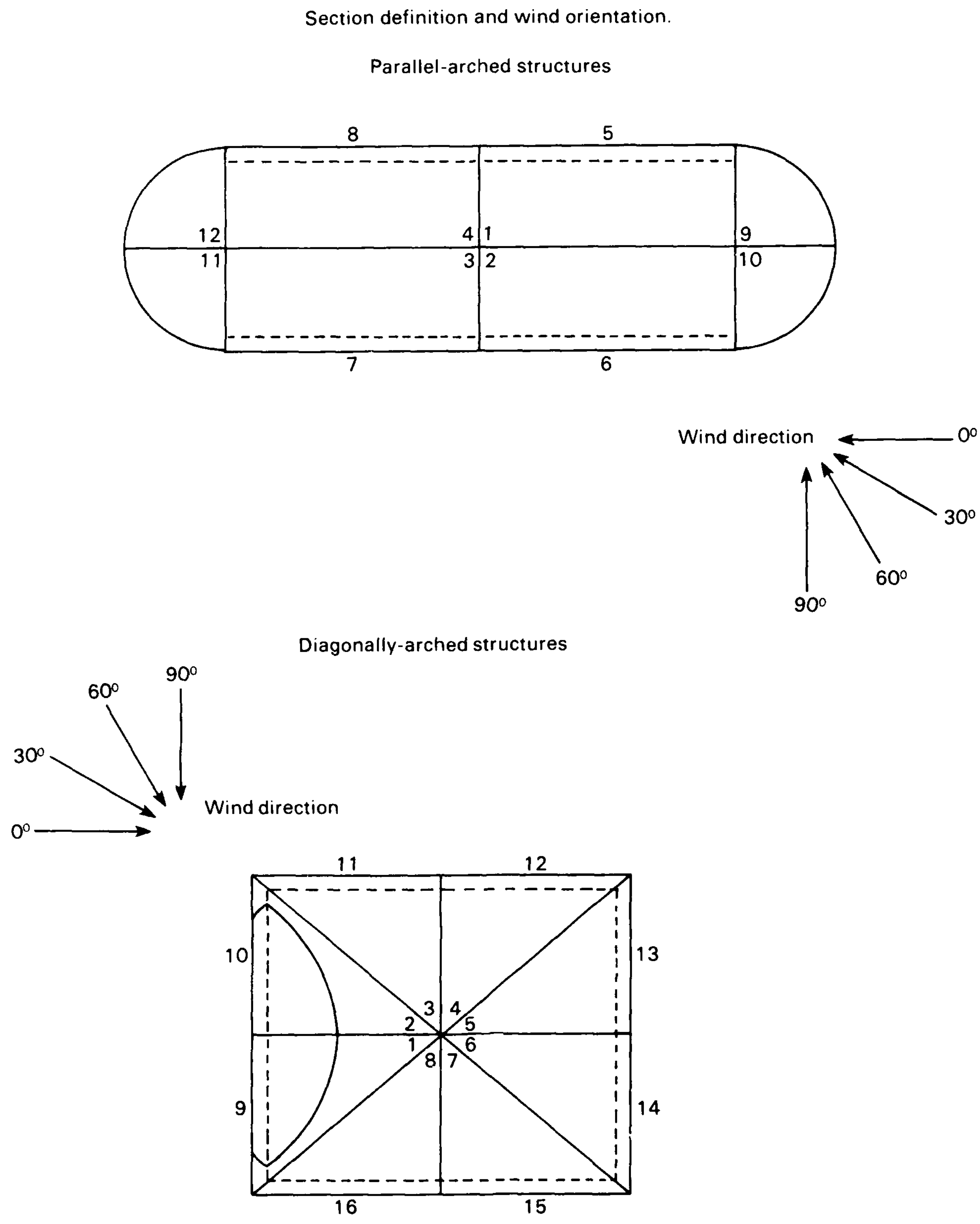
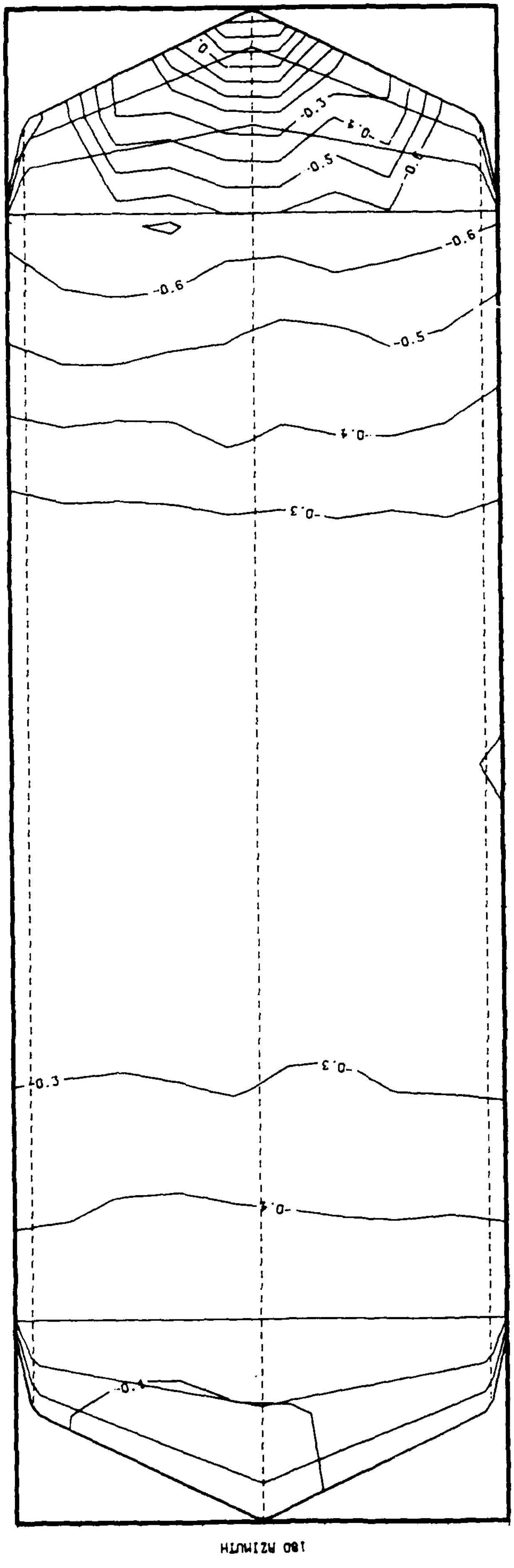


Figure 12. Structure section definitions.

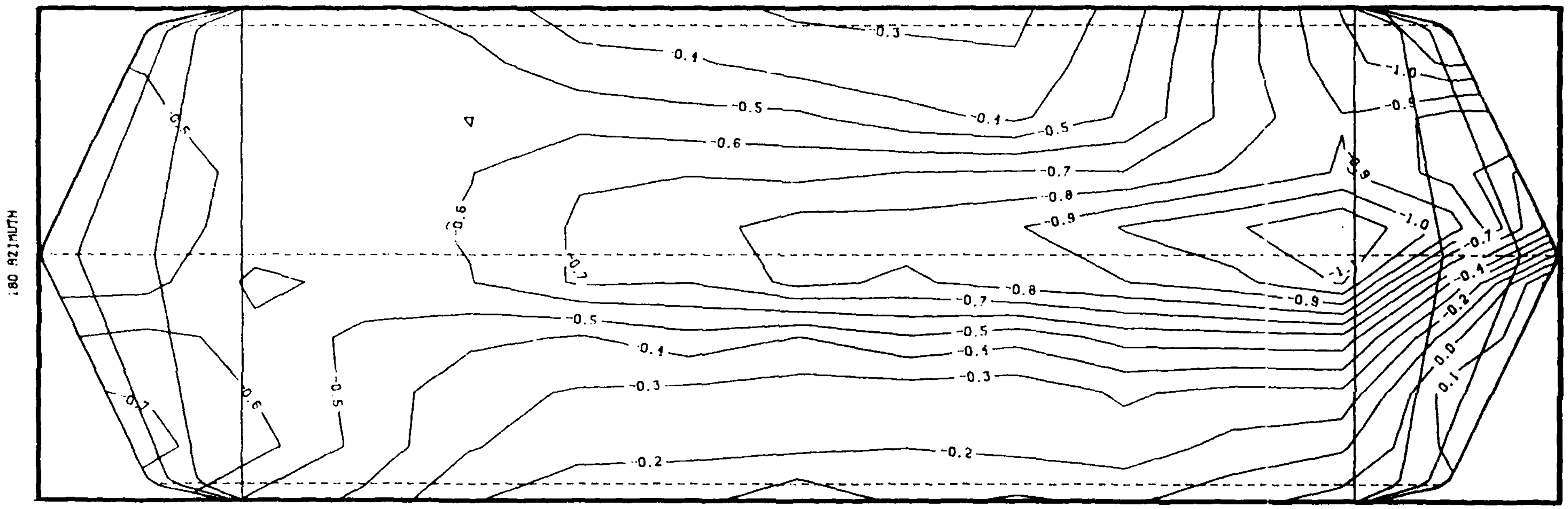
Appendix A

PRESSURE CONTOUR PLOTS

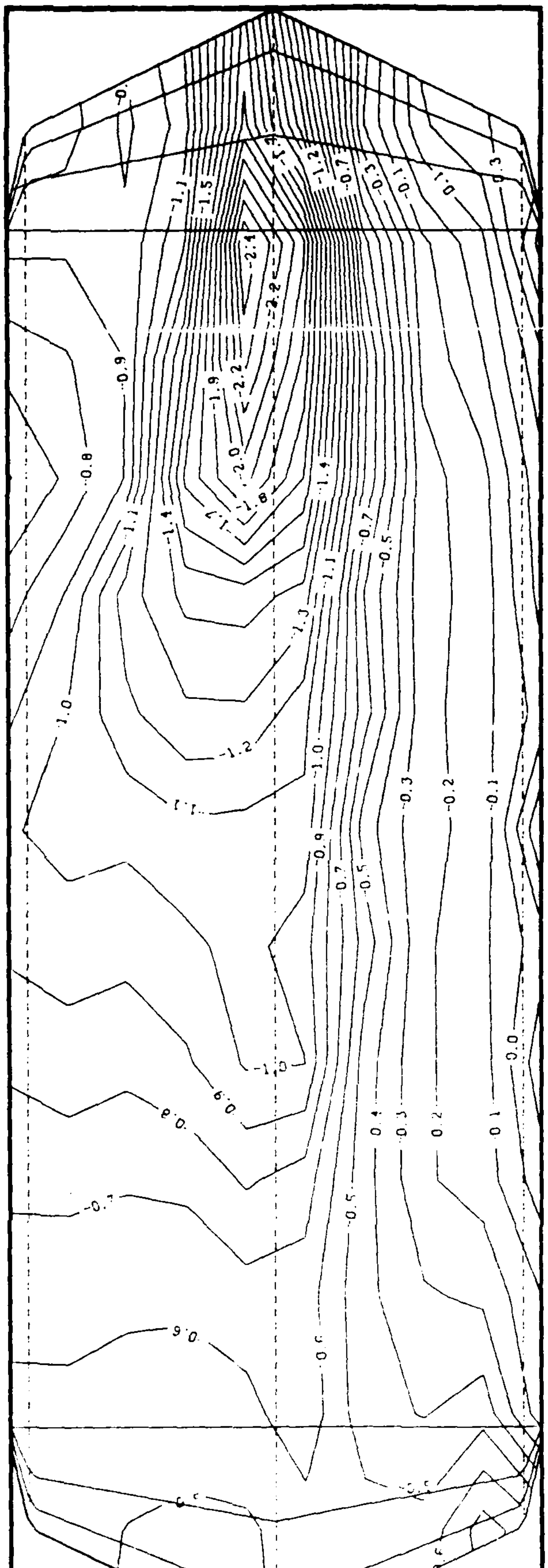
Cp CONTOURS, AZIMUTH ANGLE-0



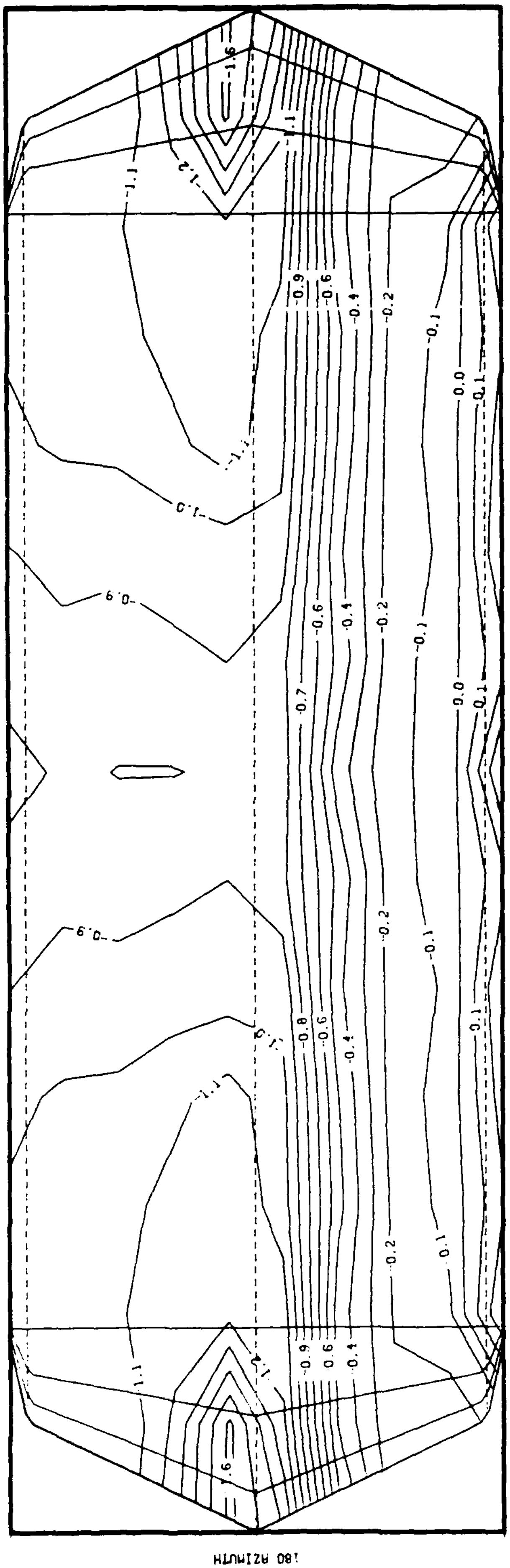
Cp CONTOURS, AZIMUTH ANGLE=30



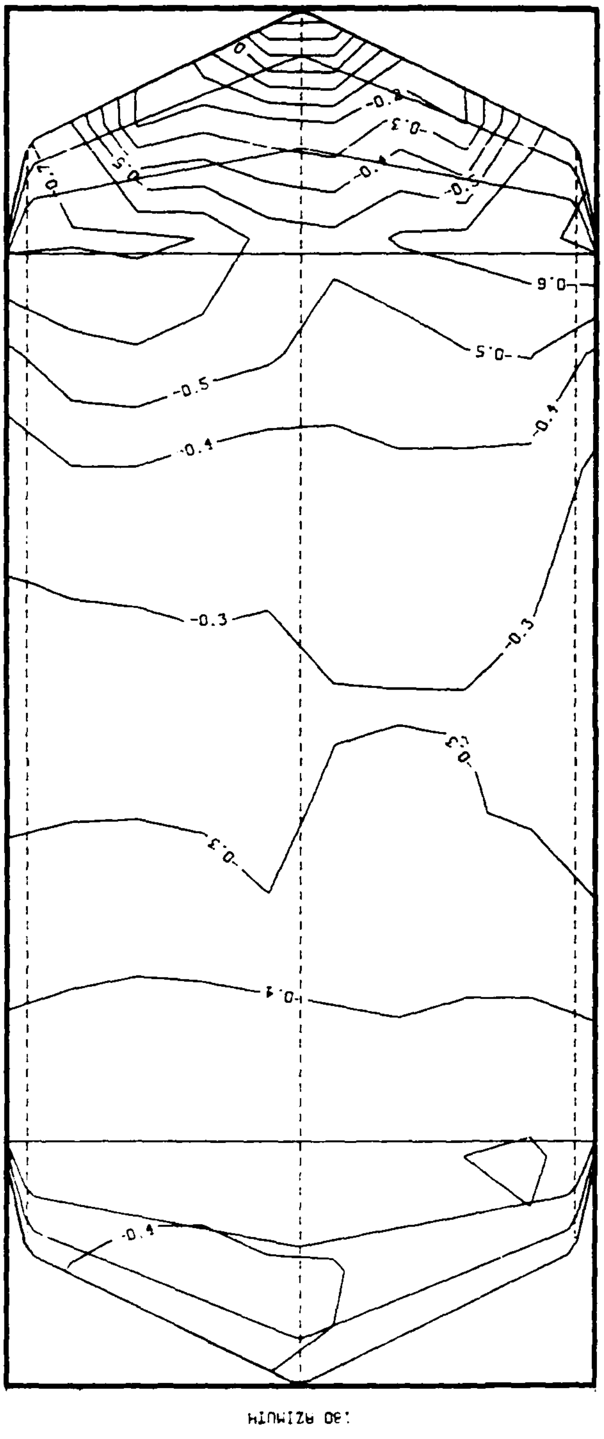
Cp CONTOURS, AZIMUTH ANGLE=60

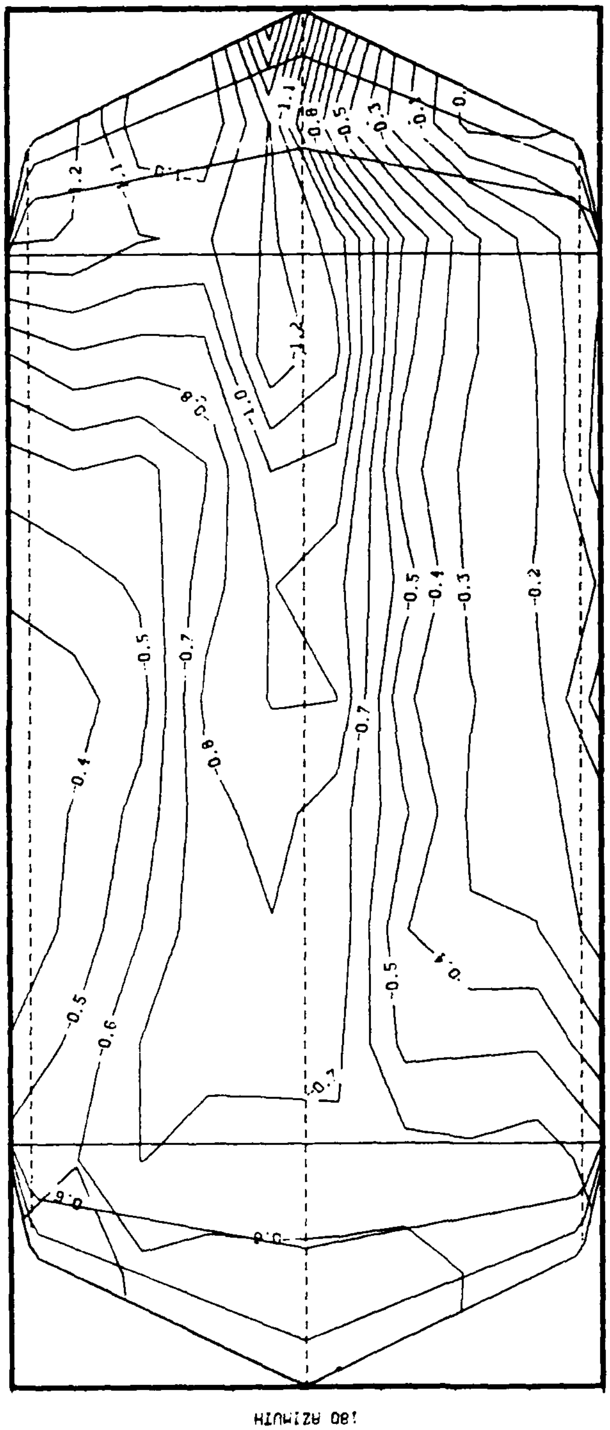


Cp CONTOURS, AZIMUTH ANGLE-90



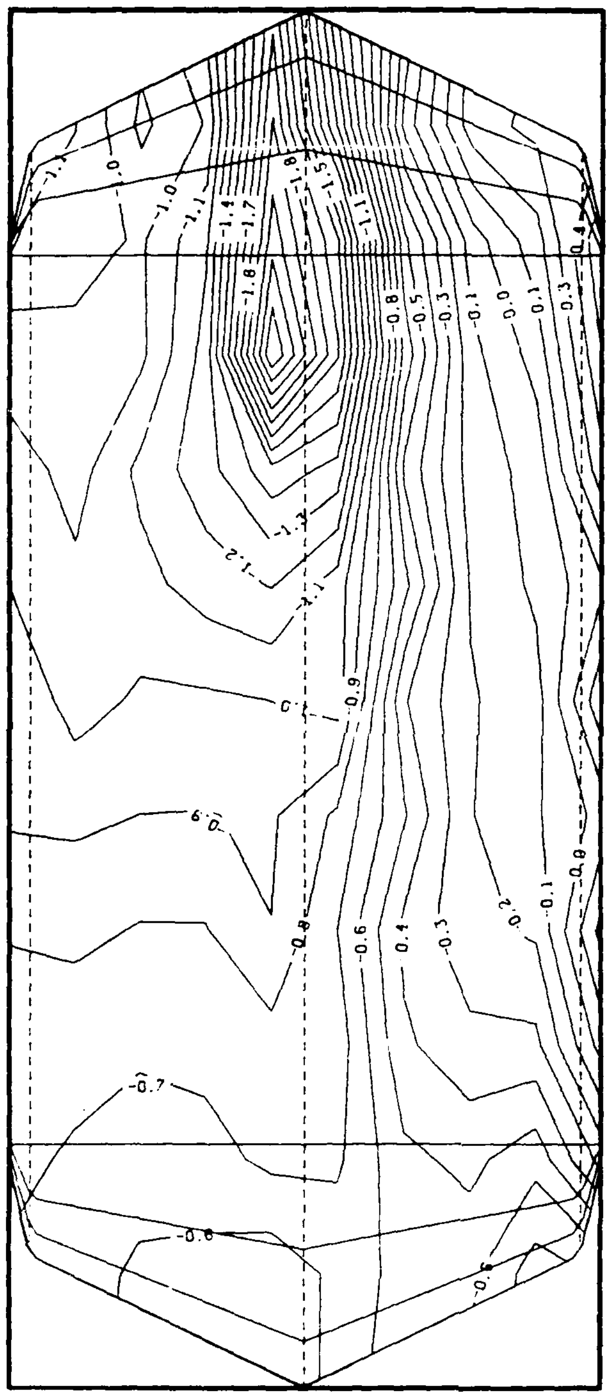
Cp CONTOURS, AZIMUTH ANGLE=0

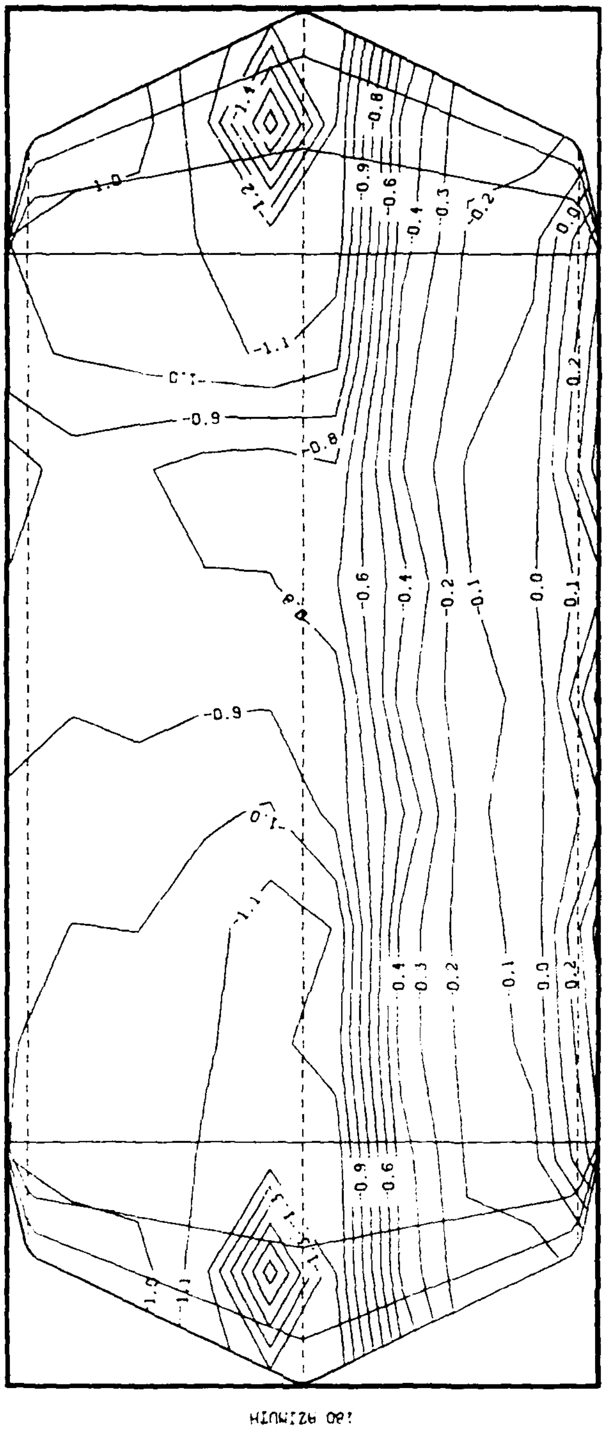




Cp CONTOURS, AZIMUTH ANGLE-30

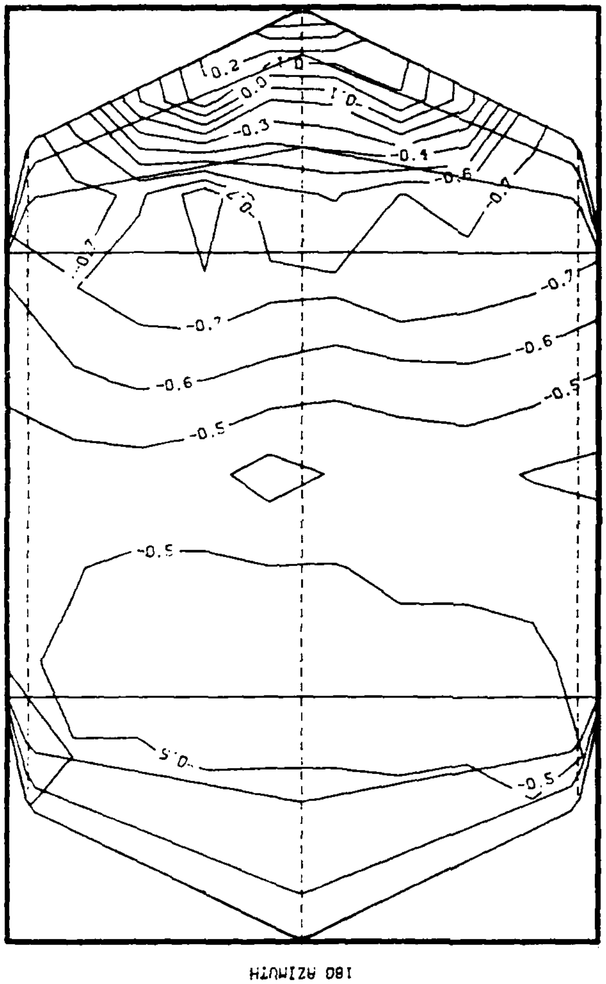
Cp CONTOURS, AZIMUTH ANGLE=60



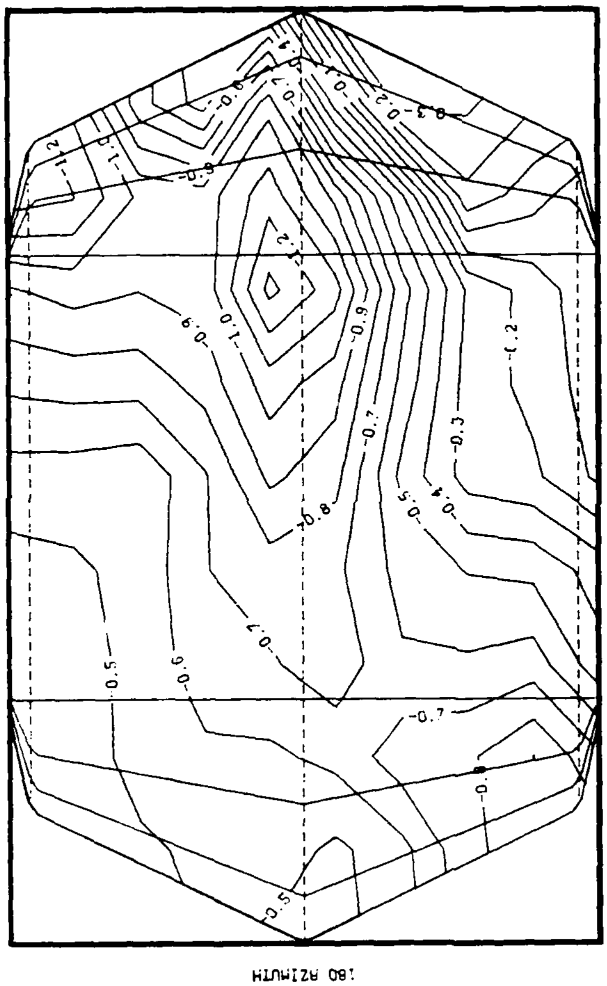


Cp CONTOURS, AZIMUTH ANGLE-90

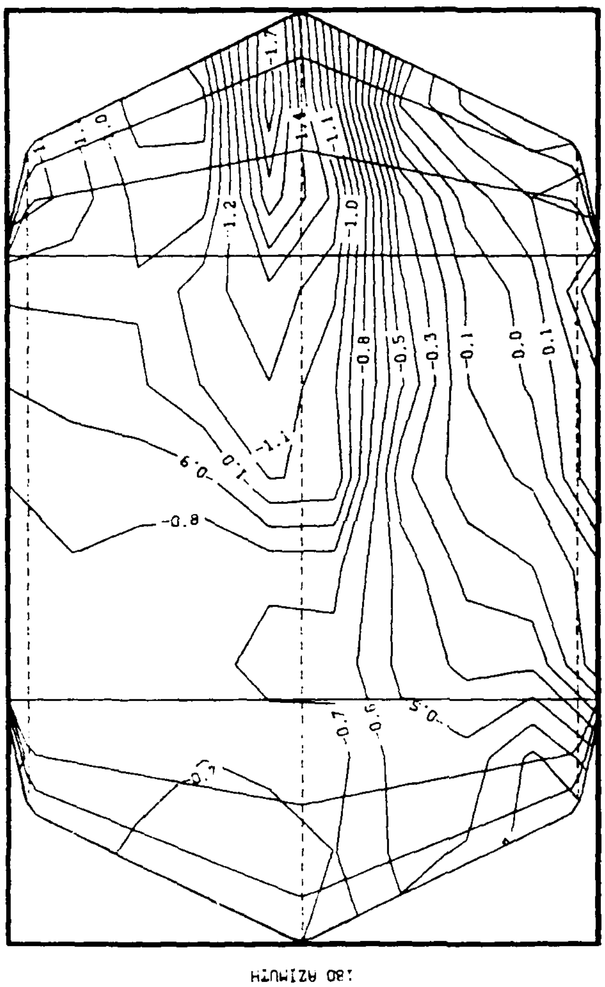
Cp CONTOURS, AZIMUTH ANGLE=0



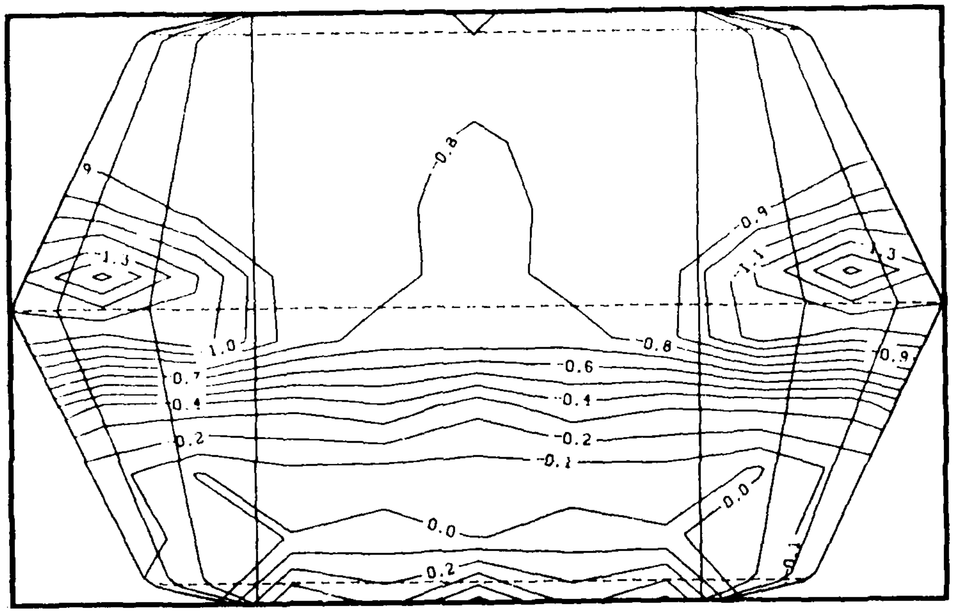
Cp CONTOURS, AZIMUTH ANGLE-30



Cp CONTOURS, AZIMUTH ANGLE=60

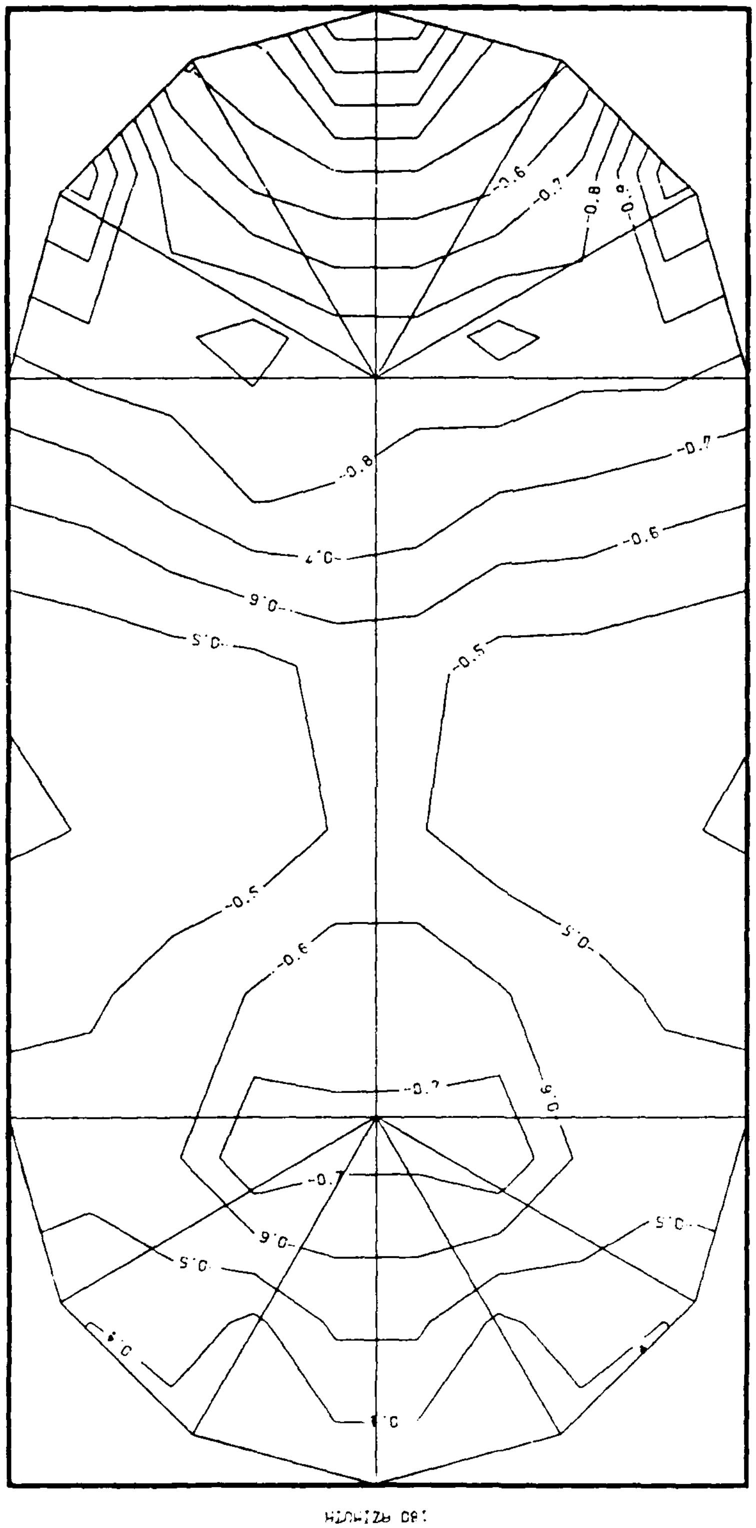


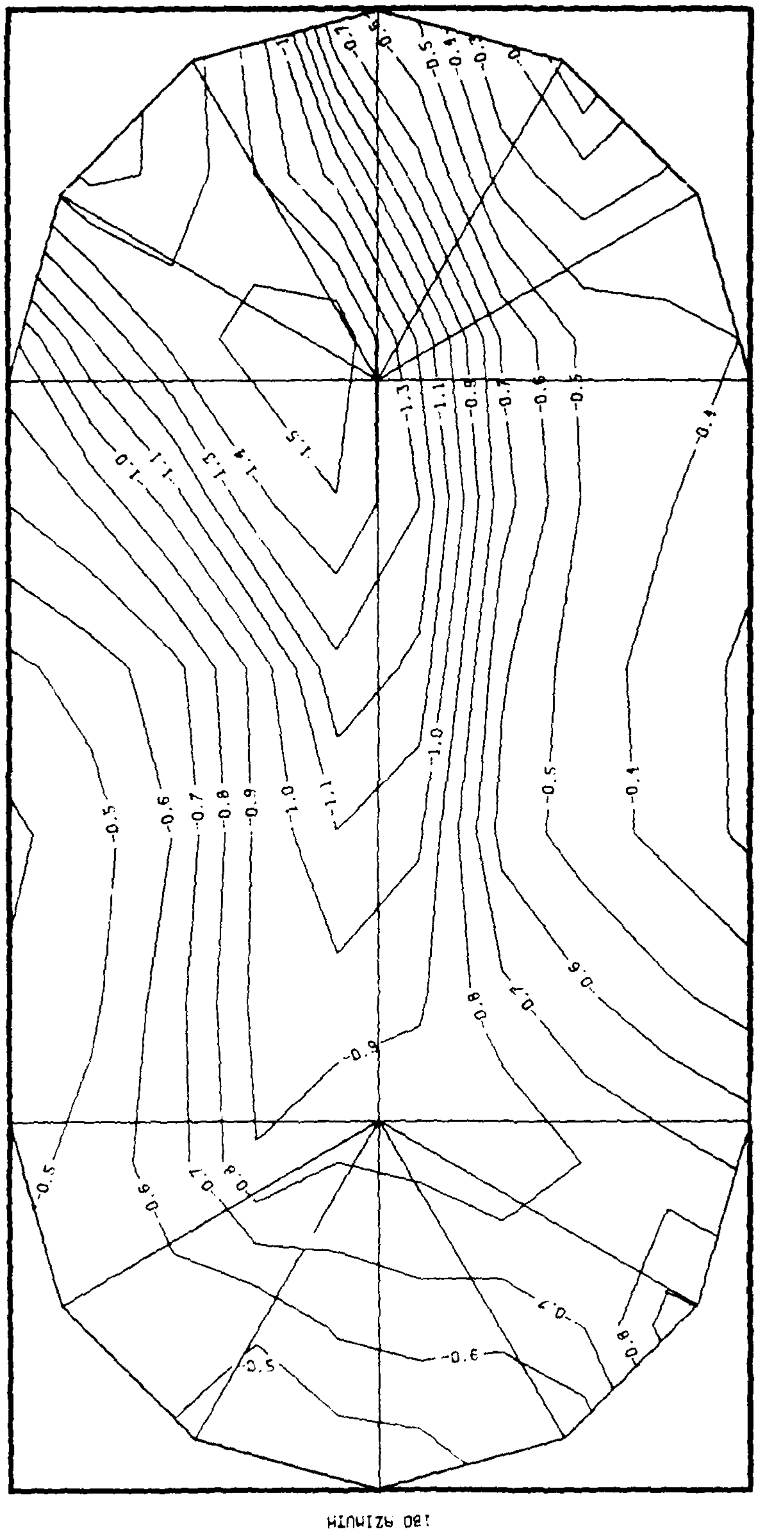
Cp CONTOURS, AZIMUTH ANGLE-90



180 AZIMUTH

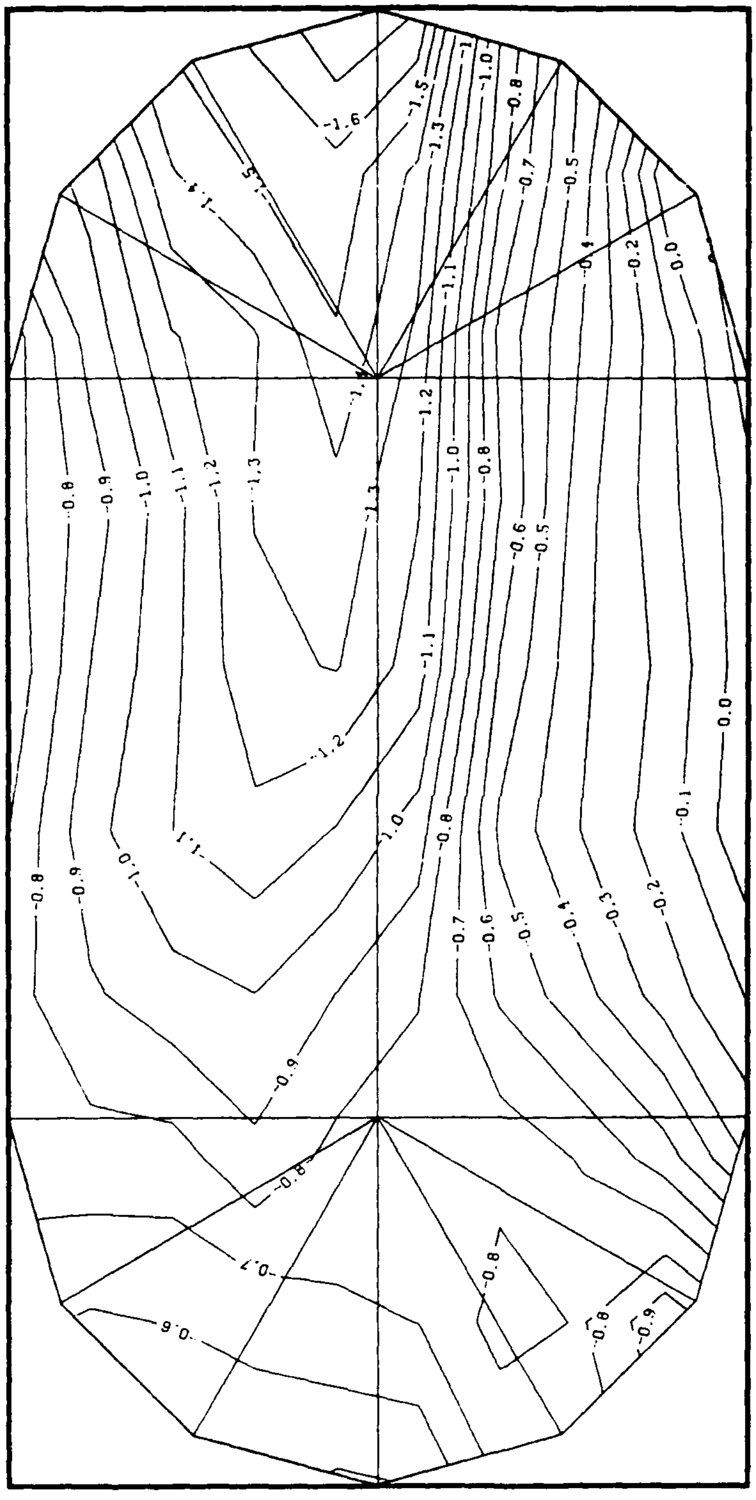
C_p CONTOURS, AZIMUTH ANGLE-0



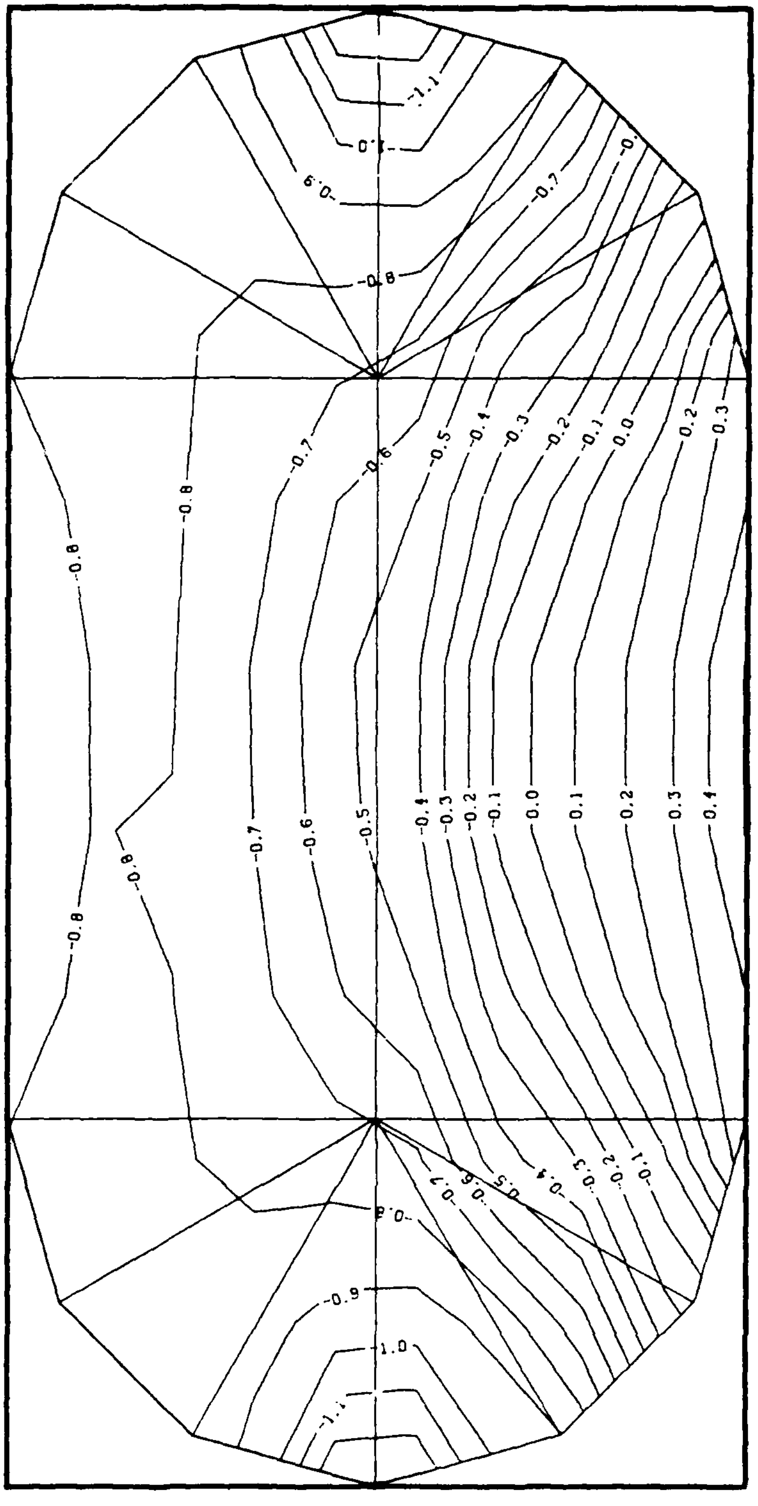


Cp CONTOURS, AZIMUTH ANGLE-30

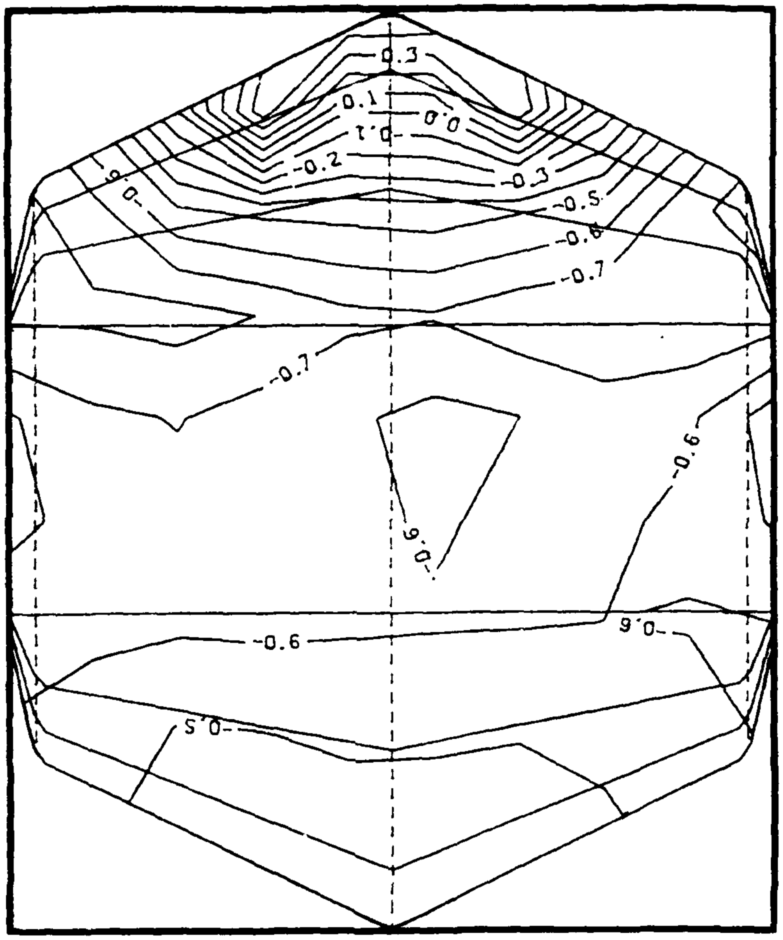
Cp CONTOURS, AZIMUTH ANGLE-60



Cp CONTOURS, AZIMUTH ANGLE-90

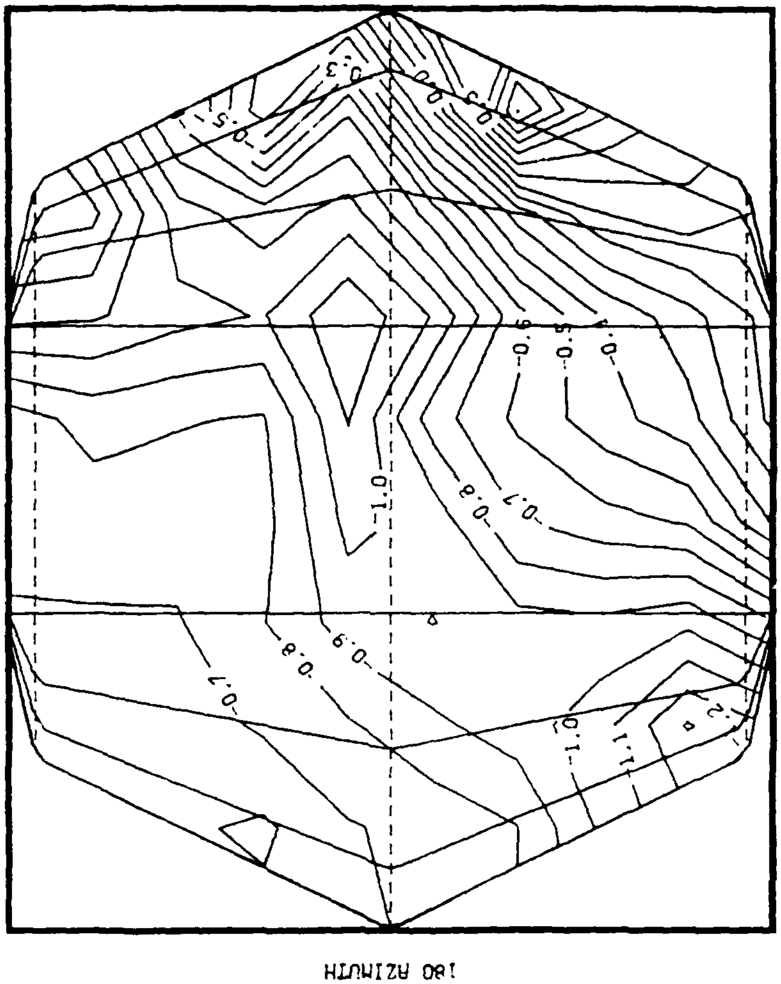


Cp CONTOURS, AZIMUTH ANGLE=0

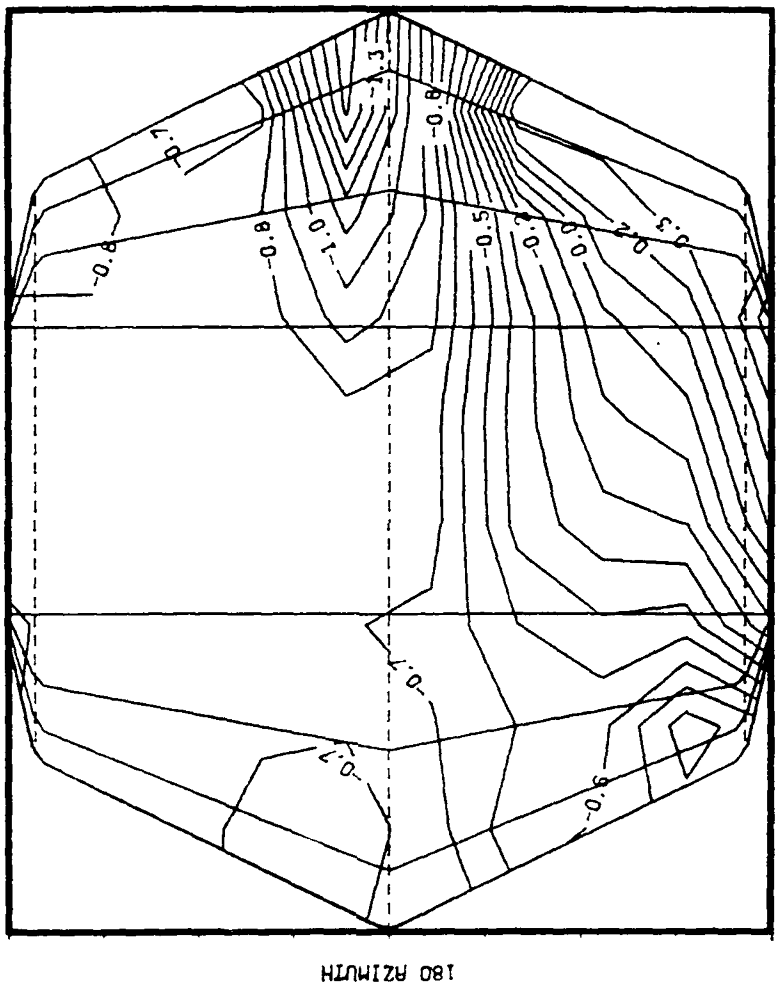


180 AZIMUTH

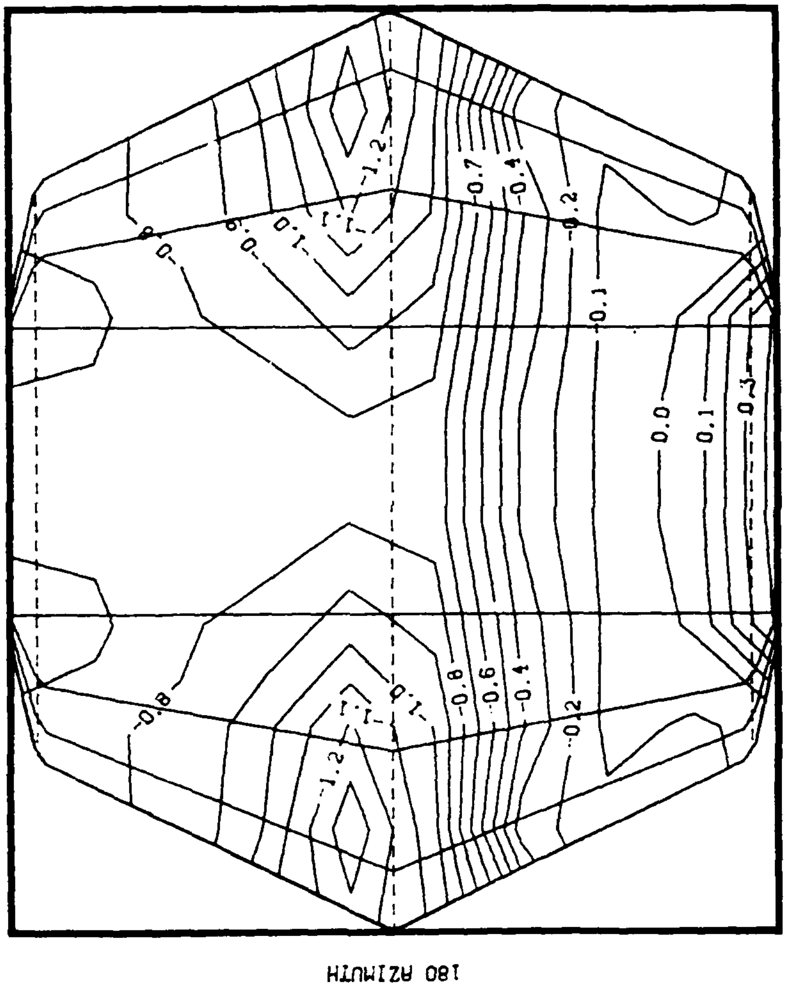
C_p CONTOURS, AZIMUTH ANGLE=30



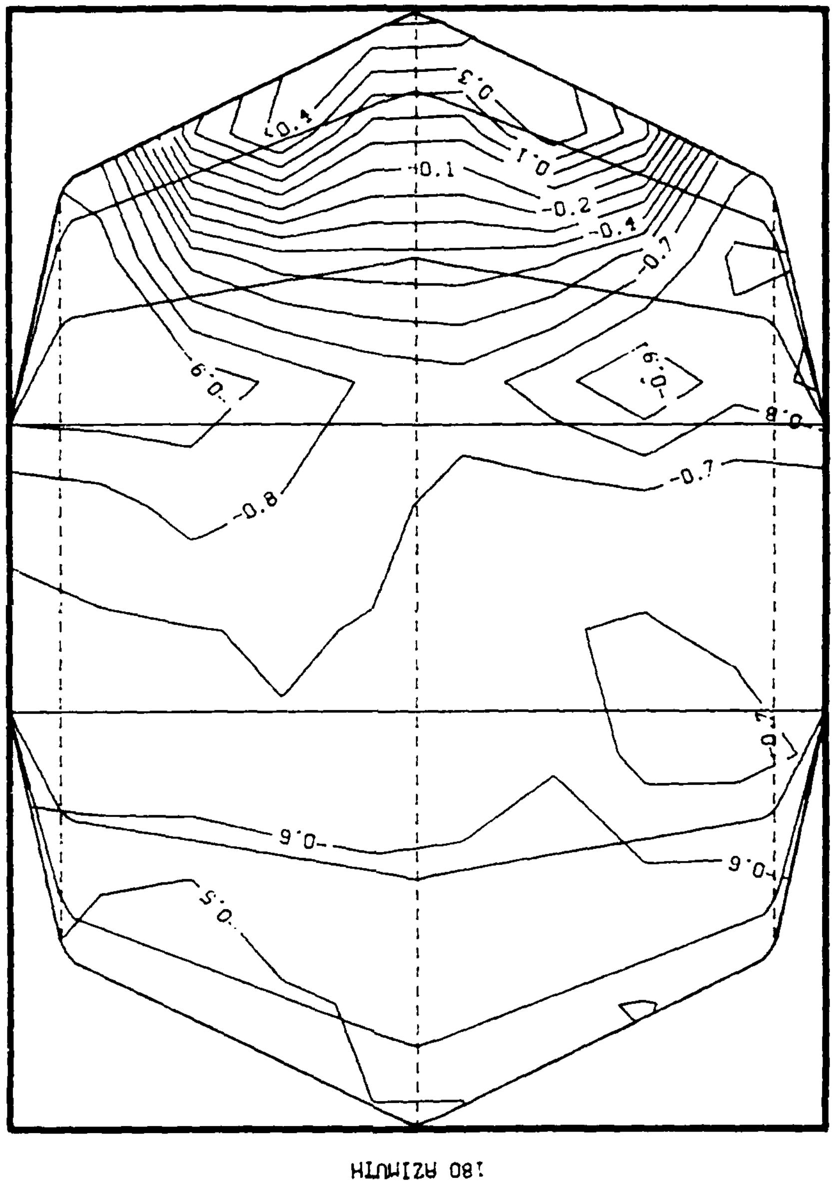
C_p CONTOURS, AZIMUTH ANGLE-60

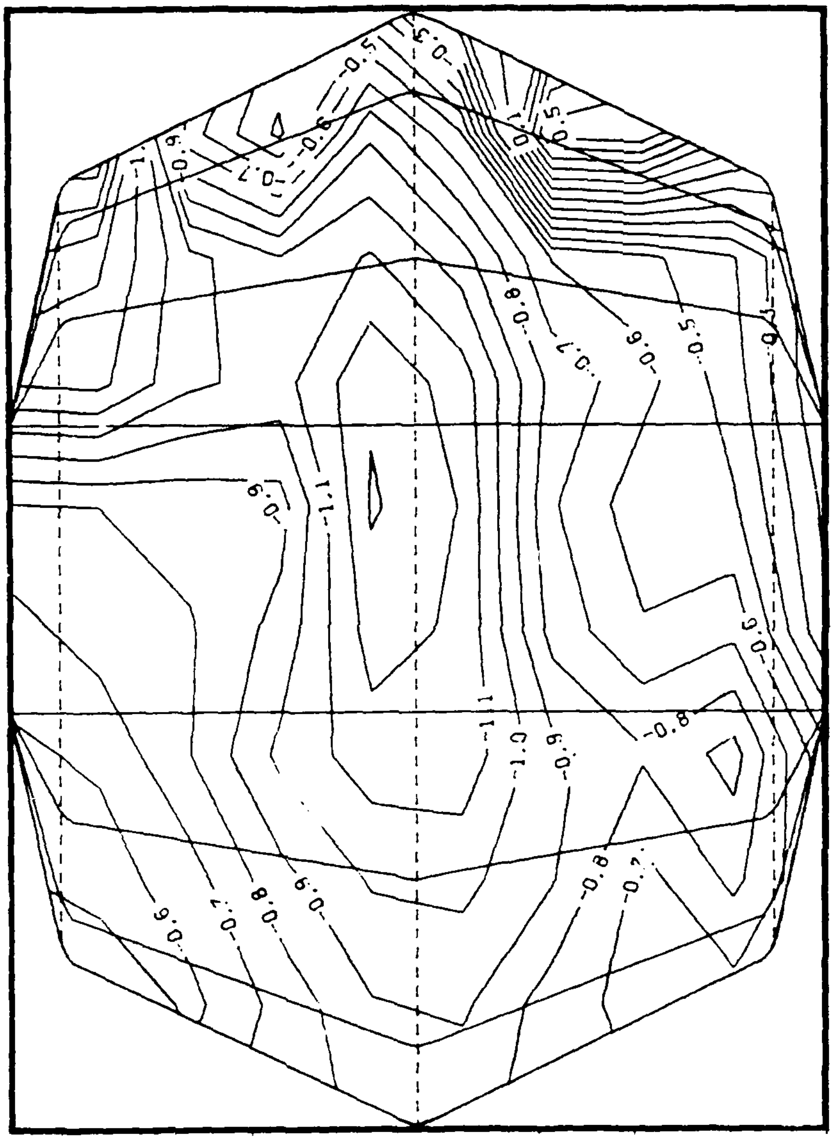


Cp CONTOURS, AZIMUTH ANGLE=90



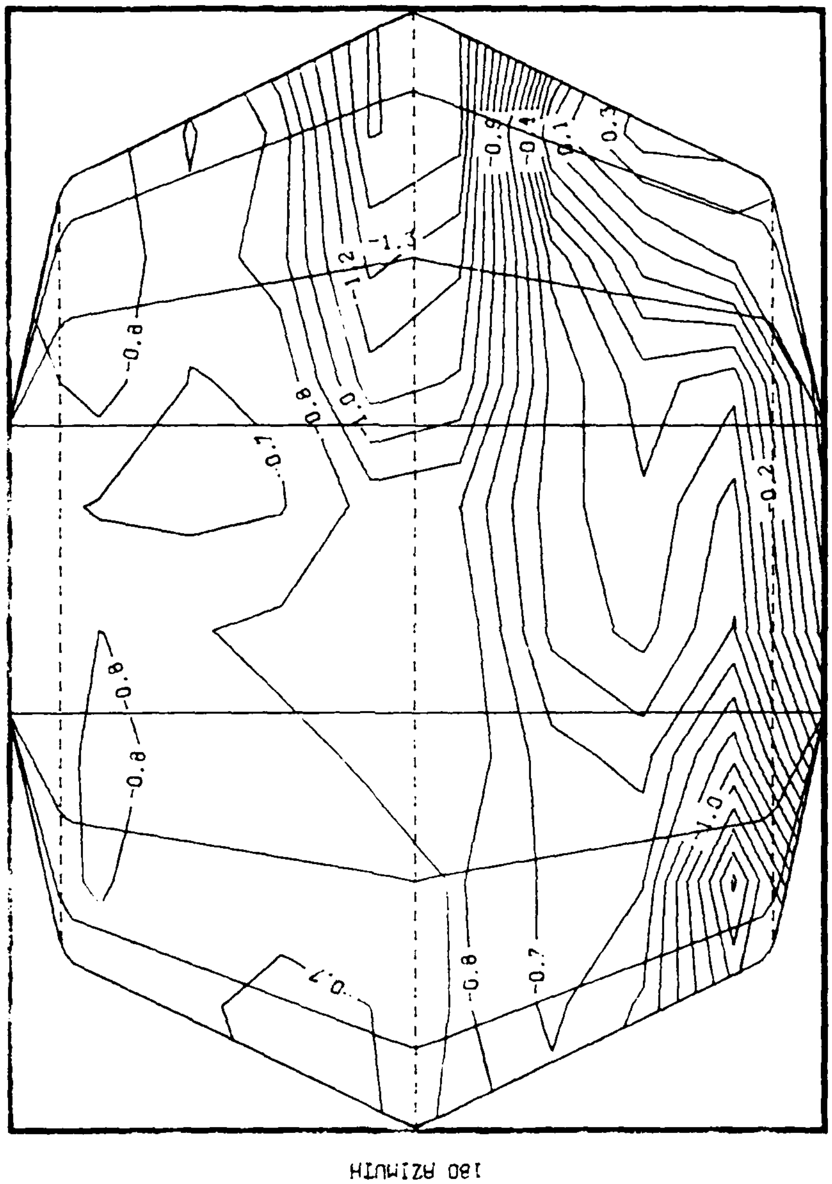
C_p CONTOURS, AZIMUTH ANGLE-0





Cp CONTOURS, AZIMUTH ANGLE=30

Cp CONTOURS, AZIMUTH ANGLE-60



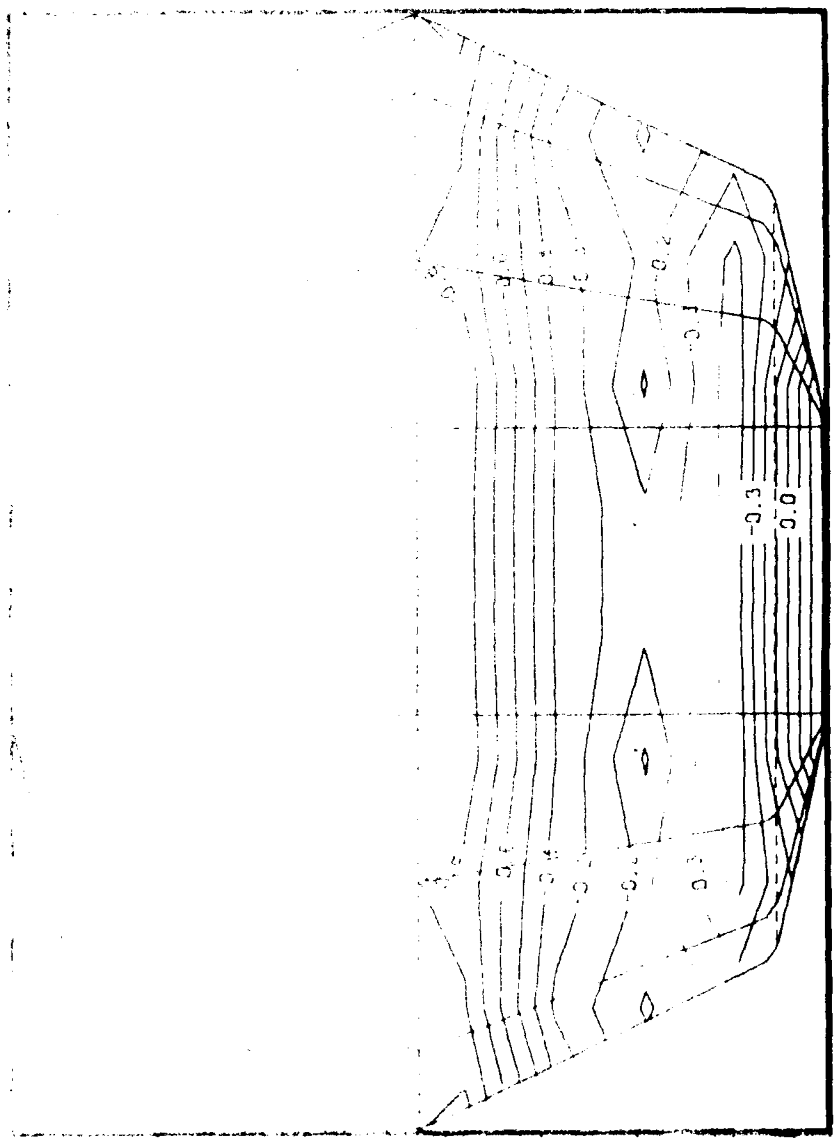
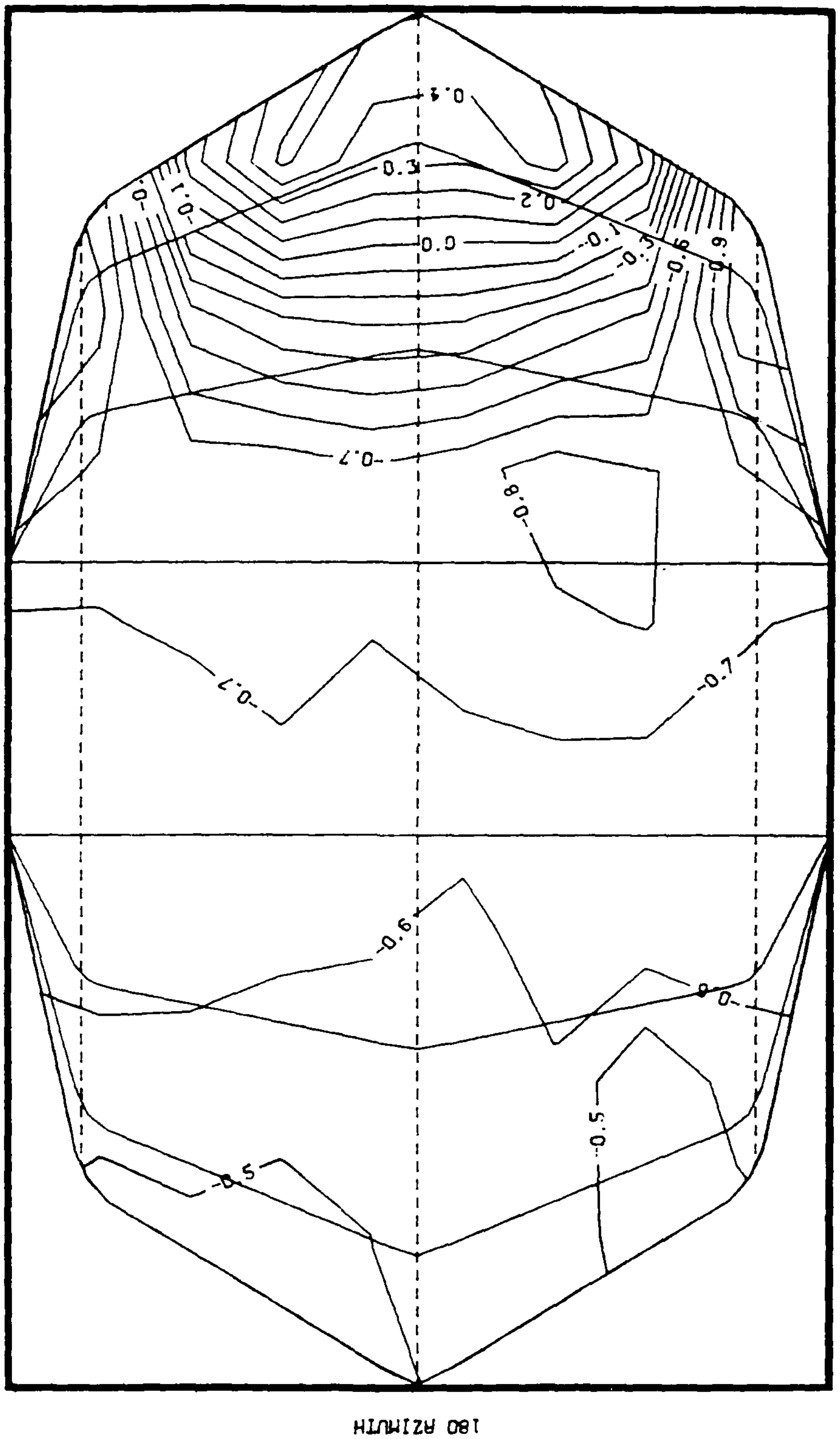
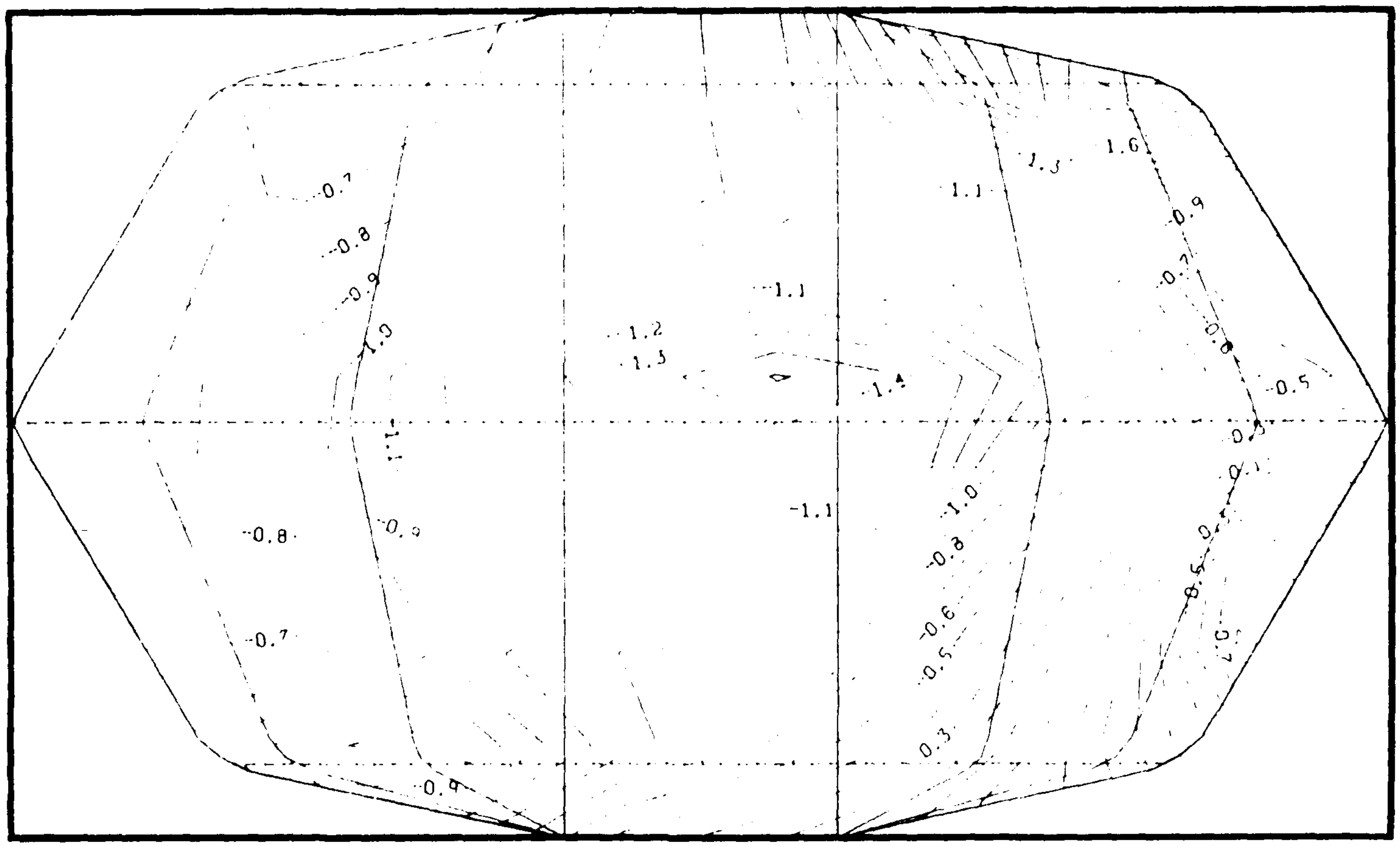


FIGURE 98

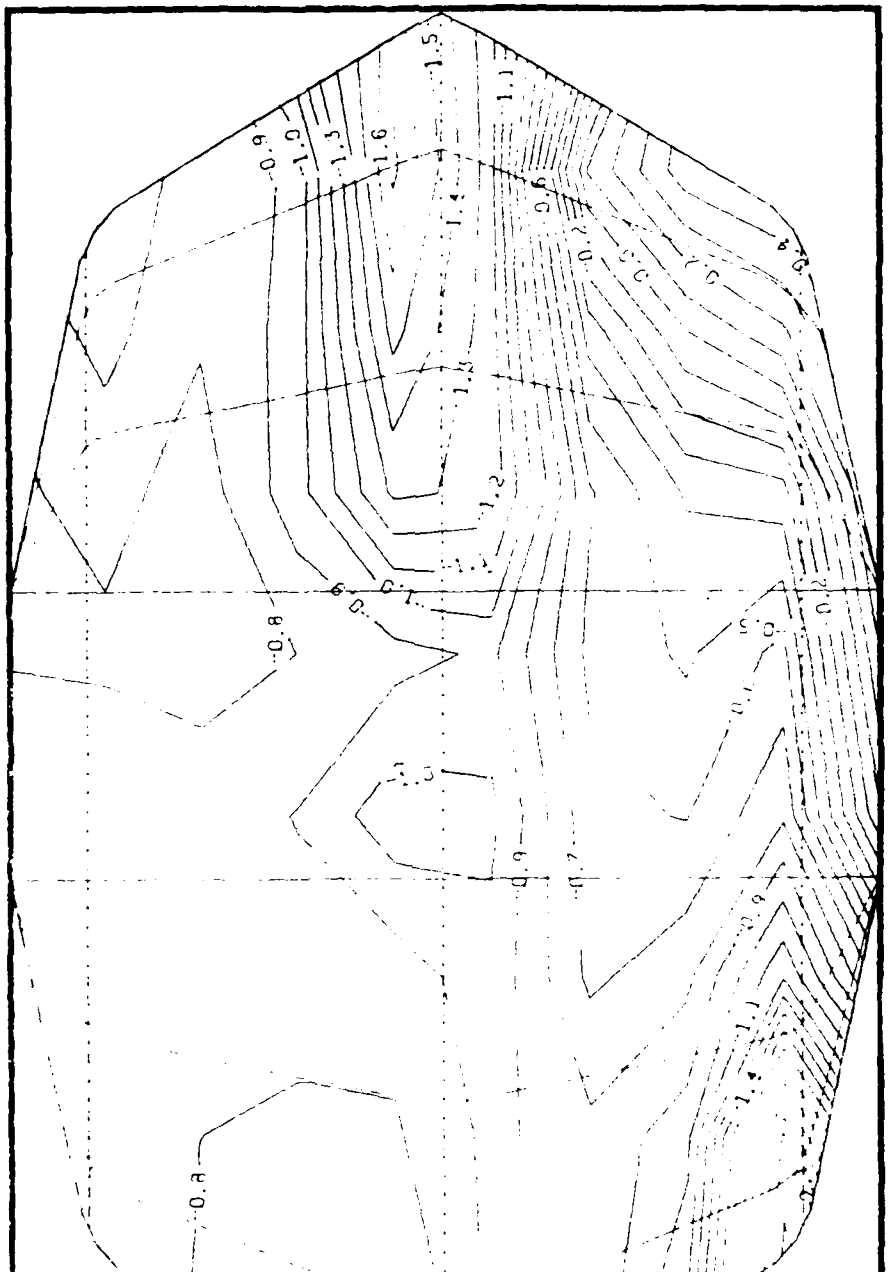
Cp CONTOURS, AZIMUTH ANGLE-0



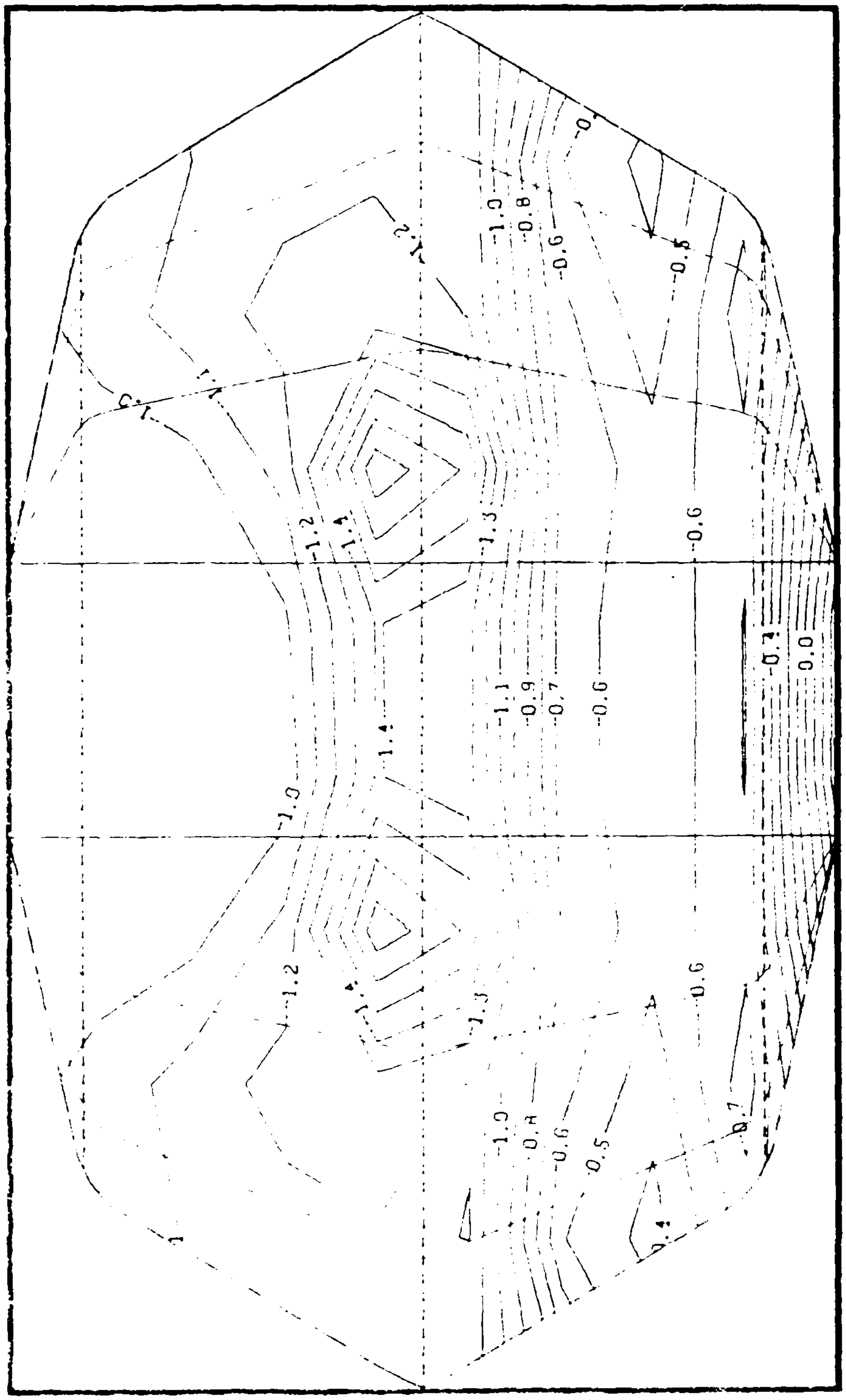
Cp CONTOURS, AZIMUTH ANGLE-30



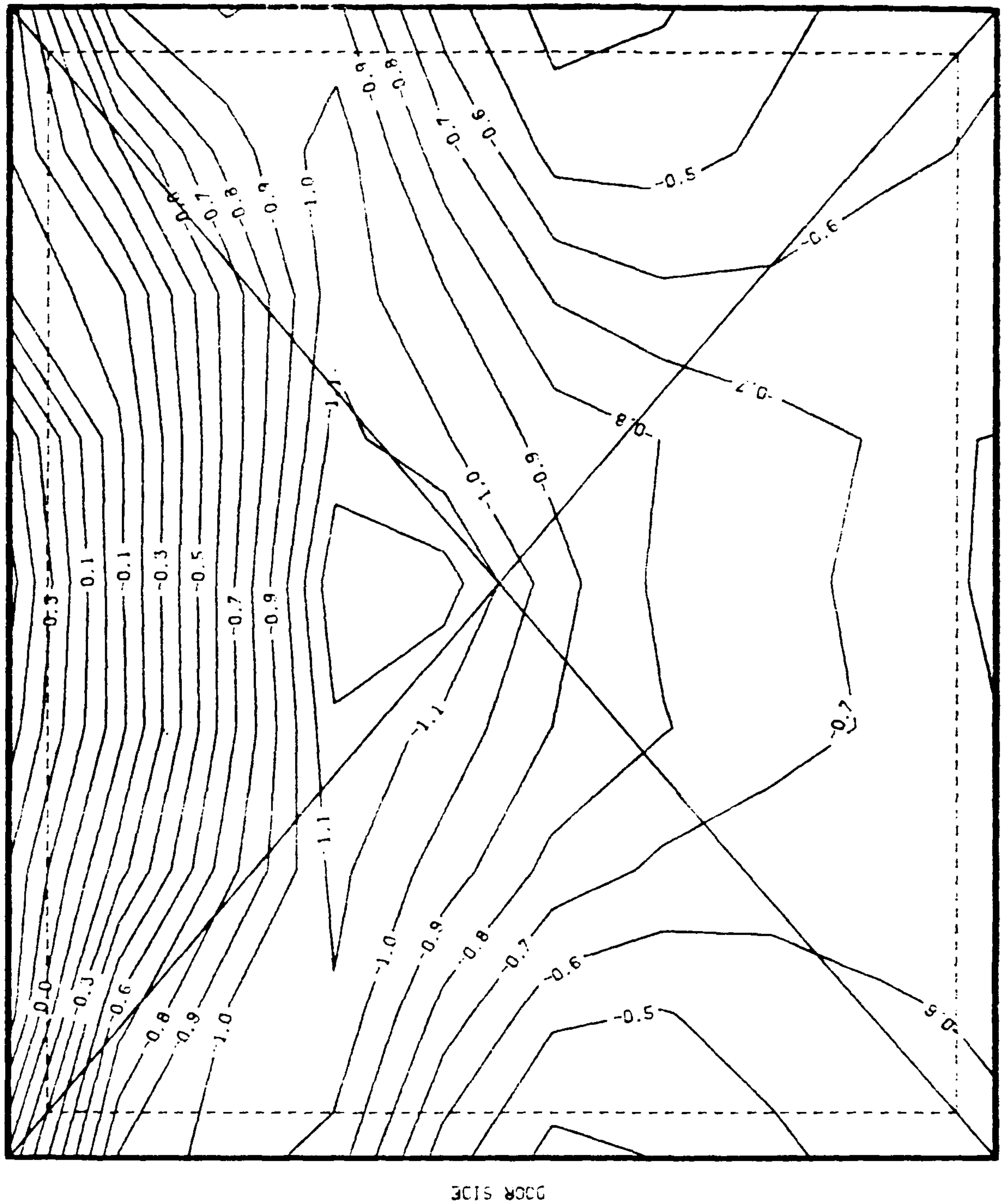
C_p CONTOURS, AZIMUTH ANGLE=60



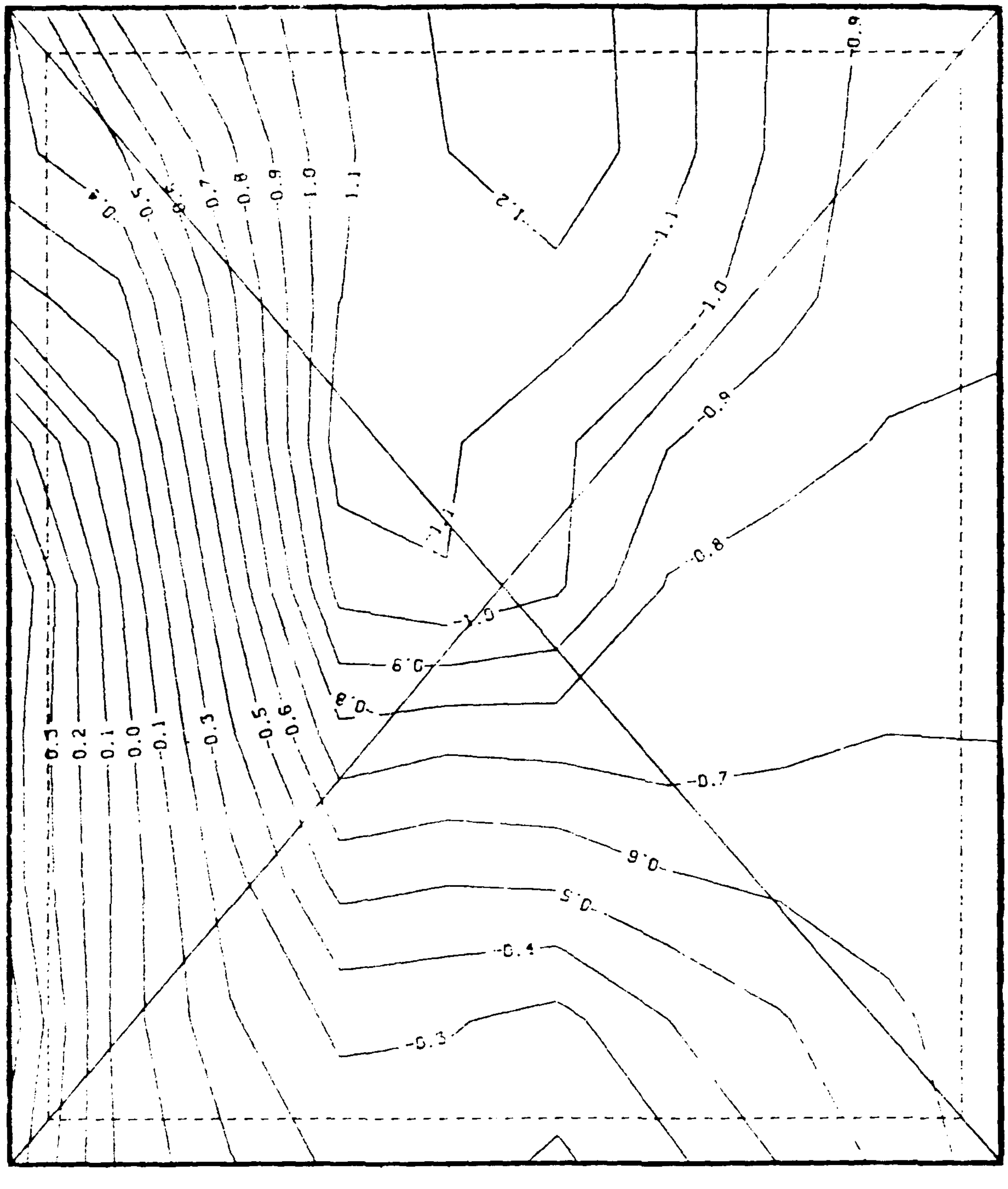
Cp CONTOURS, AZIMUTH ANGLE=90



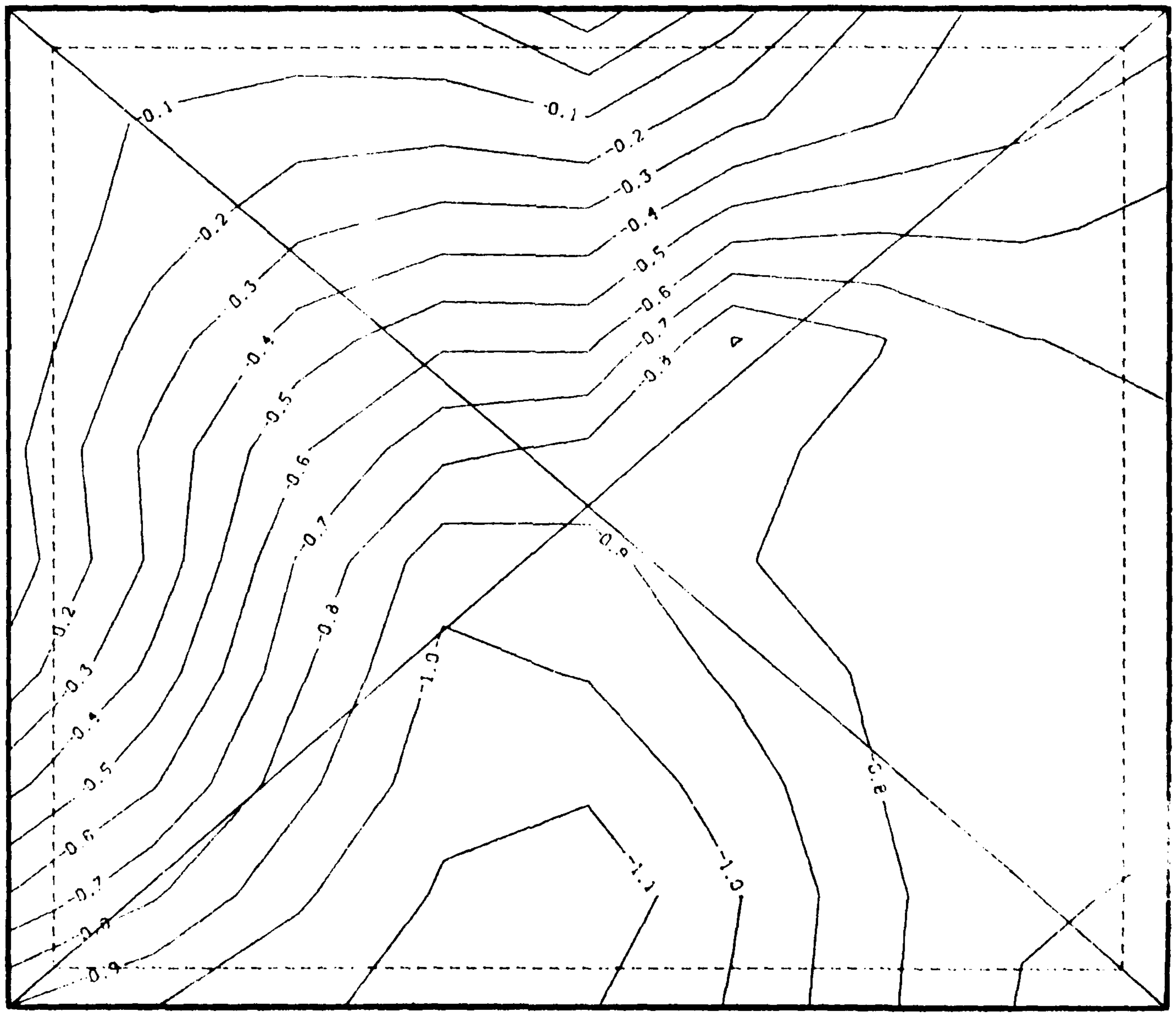
C_p CONTOURS, AZIMUTH ANGLE-30



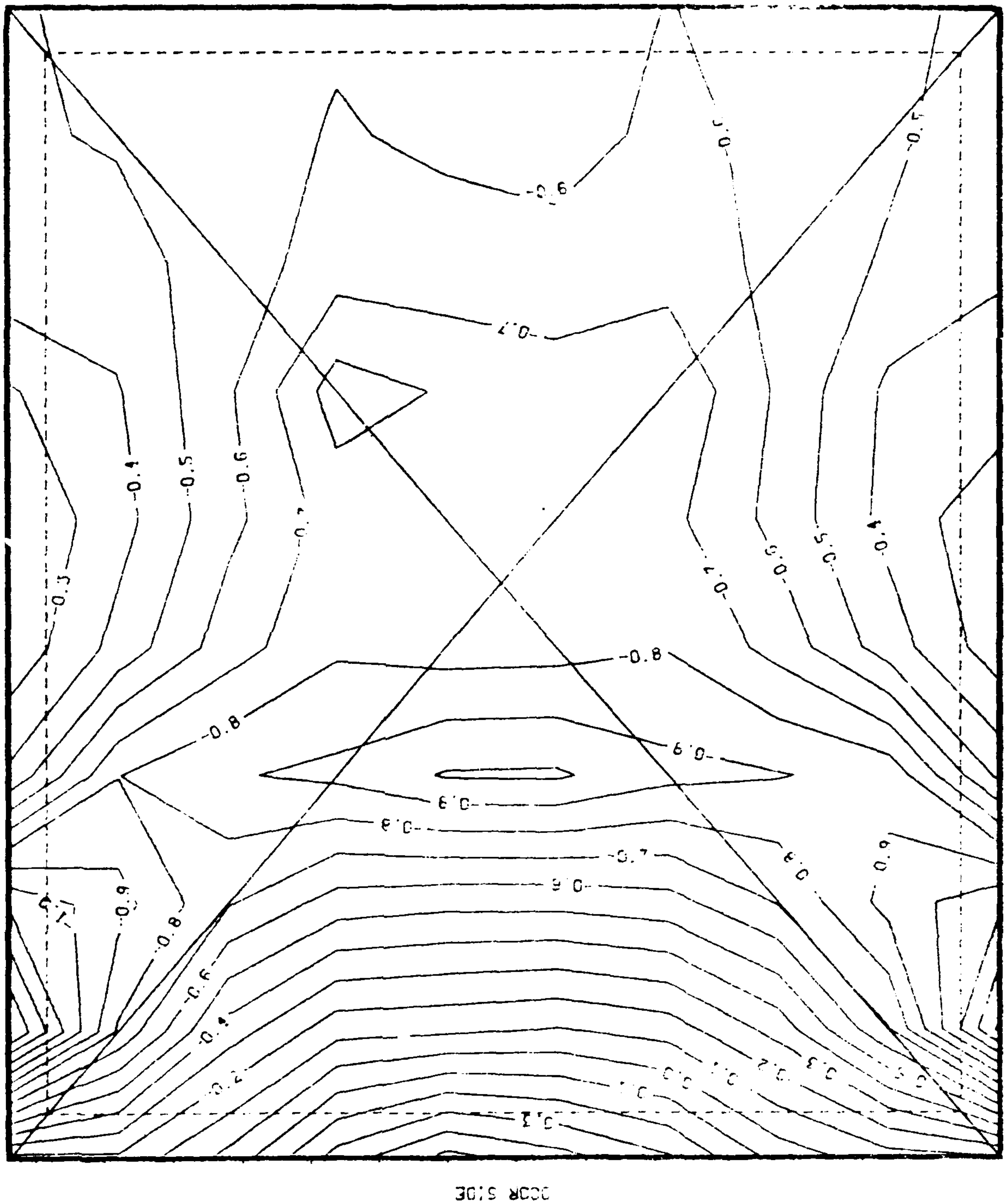
Cp CONTOURS, AZIMUTH ANGLE-60



C_p CONTOURS, AZIMUTH ANGLE-30



C_P CONTOURS, AZIMUTH ANGLE-0



Appendix B

SECTION AVERAGE PRESSURE COEFFICIENTS

Recommended Section Pressure Coefficients, Model A1

Section	Azimuth Angle			
	0	30	60	90
1	-0.40	-0.70	-1.30	-1.00
2	-0.40	-0.45	-0.65	-0.40
3	-0.35	-0.45	-0.45	-0.40
4	-0.35	-0.60	-0.85	-1.00
5	-0.40	-0.50	-0.80	-1.00
6	-0.40	-0.05	0.40	0.50
7	-0.35	-0.25	0.25	0.50
8	-0.35	-0.40	-0.80	-1.00
9	-0.35	-0.85	-1.30	-1.25
10	-0.35	-0.10	-0.30	-0.65
11	-0.45	-0.65	-0.60	-0.65
12	-0.45	-0.50	-0.55	-1.25

Recommended Section Pressure Coefficients, Model A3

Section	Azimuth Angle			
	0	30	60	90
1	-0.45	-0.80	-1.20	-1.00
2	-0.45	-0.50	-0.50	-0.40
3	-0.35	-0.50	-0.40	-0.40
4	-0.35	-0.65	-0.85	-1.00
5	-0.45	-0.60	-1.05	-0.95
6	-0.45	-0.10	0.50	0.55
7	-0.35	-0.30	0.25	0.55
8	-0.35	-0.45	-0.85	-0.95
9	-0.35	-0.95	-1.25	-1.15
10	-0.35	-0.10	-0.25	-0.60
11	-0.40	-0.60	-0.65	-0.60
12	-0.40	-0.60	-0.65	-1.15

Recommended Section Pressure Coefficients, Model A5

Section	Azimuth Angle			
	0	30	60	90
1	-0.60	-0.90	-1.05	-0.85
2	-0.60	-0.55	-0.40	-0.30
3	-0.50	-0.60	-0.45	-0.30
4	-0.50	-0.60	-0.80	-0.85
5	-0.55	-0.80	-0.95	-0.85
6	-0.55	-0.10	0.50	0.60
7	-0.50	-0.40	0.25	0.60
8	-0.50	-0.55	-0.75	-0.85
9	-0.35	-0.90	-1.20	-1.05
10	-0.35	-0.05	-0.20	-0.45
11	-0.50	-0.75	-0.65	-0.45
12	-0.50	-0.55	-0.75	-1.05

Recommended Section Pressure Coefficients, Model A6

Section	Azimuth Angle			
	0	30	60	90
1	-0.70	-0.90	-0.80	-0.80
2	-0.70	-0.55	-0.30	-0.25
3	-0.65	-0.75	-0.40	-0.25
4	-0.65	-0.80	-0.80	-0.80
5	-0.60	-0.90	-0.80	-0.80
6	-0.60	-0.15	0.50	0.65
7	-0.60	-0.45	0.35	0.65
8	-0.60	-0.75	-0.80	-0.80
9	-0.35	-0.85	-0.90	-1.00
10	-0.35	-0.05	-0.15	-0.45
11	-0.55	-1.00	-0.65	-0.45
12	-0.55	-0.70	-0.70	-1.00

Recommended Section Pressure Coefficients, Model B6

Section	Azimuth Angle			
	0	30	60	90
1	-0.80	-1.00	-0.75	-0.85
2	-0.80	-0.75	-0.55	-0.45
3	-0.70	-0.85	-0.60	-0.45
4	-0.70	-0.90	-0.80	-0.85
5	-0.75	-0.90	-0.80	-0.80
6	-0.75	-0.10	0.50	0.75
7	-0.65	-0.10	0.40	0.75
8	-0.70	-0.70	-0.80	-0.80
9	-0.30	-1.00	-1.00	-0.80
10	-0.30	-0.10	-0.25	-0.45
11	-0.60	-0.80	-0.80	-0.45
12	-0.60	-0.75	-0.80	-0.80

Recommended Section Pressure Coefficients, Model C6

Section	Azimuth Angle			
	0	30	60	90
1	-0.75	-1.10	-0.85	-1.10
2	-0.75	-0.90	-0.65	-0.85
3	-0.70	-0.90	-0.80	-0.85
4	-0.70	-1.05	-0.90	-1.10
5	-0.70	-1.00	-0.80	-1.00
6	-0.70	-0.10	0.50	0.85
7	-0.70	-0.10	0.50	0.85
8	-0.70	-0.85	-0.85	-1.00
9	-0.25	-1.05	-1.10	-1.15
10	-0.25	-0.10	-0.30	-0.65
11	-0.55	-0.85	-1.00	-0.65
12	-0.55	-0.85	-0.85	-1.15

Recommended Section Pressure Coefficients, Model D

Section	Azimuth Angle			
	0	30	60	90
1	-0.65	-1.05	-1.10	-0.75
2	-0.65	-0.75	-0.55	-0.10
3	-0.55	-0.70	-0.50	-0.10
4	-0.55	-0.75	-1.00	-0.75
5	-0.60	-0.65	-0.70	-0.80
6	-0.60	-0.35	0.15	0.50
7	-0.55	-0.40	0.05	0.50
8	-0.55	-0.50	-0.75	-0.80
9	-0.70	-1.35	-1.35	-0.90
10	-0.70	-0.55	-0.75	-0.60
11	-0.55	-0.70	-0.70	-0.60
12	-0.55	-0.60	-0.70	-0.90

Recommended Section Pressure Coefficients, Model E

Section	Azimuth Angle			
	0	30	60	90
1	-0.50	-0.60	-0.50	-0.65
2	-0.50	-0.35	-0.35	-0.95
3	-0.75	-0.30	-0.25	-0.55
4	-0.55	-0.50	-0.50	-0.55
5	-0.65	-0.70	-1.00	-0.95
6	-0.65	-0.75	1.05	0.65
7	-0.55	-0.90	0.85	0.70
8	-0.75	-1.00	-0.70	-0.70
9	-0.65	-0.35	-0.40	-0.50
10	-0.65	-0.05	-0.10	-0.80
11	-0.80	-0.10	-0.40	-0.65
12	-0.40	-0.25	-0.10	-0.65
13	-0.60	-0.60	-0.90	-0.80
14	-0.60	-0.75	-1.05	-0.50
15	-0.40	-0.85	-0.80	-0.60
16	-0.80	-1.05	-0.65	-0.60

Appendix C

SECTION PEAK PRESSURE COEFFICIENTS

PEAK PRESSURE COEFFICIENTS IN EACH SECTION, MODEL A1

Section	Azimuth Angle			
	0	30	60	90
1	-0.80	-1.26	-3.06	-1.21
2	-0.80	-1.20	-2.13	-1.17
3	-0.50	-0.83	-1.08	-1.17
4	-0.50	-0.85	-1.11	-1.21
5	-0.56	-0.89	-0.91	-1.00
6	-0.56	-0.07 (0.18)	0.69	0.56
7	-0.41	-0.32 (0.02)	0.38	0.56
8	-0.41	-0.46	-0.98	-1.00
9	-0.98 (0.78)	-1.62	-2.33	-1.77
10	-0.98 (0.78)	-0.93 (0.78)	-1.76 (0.83)	-1.49 (0.45)
11	-0.59	-1.07	-1.36	-1.49 (0.45)
12	-0.59	-0.65	-0.60	-1.77

PEAK PRESSURE COEFFICIENTS IN EACH SECTION, MODEL A3

Section	Azimuth Angle			
	0	30	60	90
1	-0.80	-1.45	-2.44	-1.17
2	-0.80	-1.30	-1.79	-1.11
3	-0.54	-0.91	-1.06	-1.11
4	-0.54	-0.91	-1.15	-1.17
5	-0.60	-0.93	-1.09	-1.00
6	-0.60	-0.09 (0.11)	0.69	0.57
7	-0.44	-0.32 (0.09)	0.34	0.57
8	-0.44	-0.41	-0.89	-1.00
9	-0.96 (0.78)	-2.04	-2.20	-1.87
10	-0.96 (0.78)	-1.04 (0.68)	-1.65 (0.83)	-1.43 (0.45)
11	-0.61	-0.96	-1.36	-1.43 (0.45)
12	-0.61	-0.85	-0.76	-1.87

PEAK PRESSURE COEFFICIENTS IN EACH SECTION, MODEL A6

Section	Azimuth Angle			
	0	30	60	90
1	-0.93	-1.48	-0.94	-0.82
2	-0.93	-1.20	-0.81	-0.83
3	-0.70	-1.16	-0.78	-0.83
4	-0.70	-1.12	-0.82	-0.82
5	-0.64	-0.87	-0.77	-0.82
6	-0.64	-0.17 (0.06)	0.56	0.67
7	-0.57	-0.43	0.46	0.67
8	-0.57	-0.75	-0.76	-0.82
9	-1.07 (0.76)	-1.69	-2.06	-1.57
10	-1.07 (0.76)	-0.93 (0.82)	-1.06 (0.89)	-1.17 (0.59)
11	-0.78	-1.88	-1.33 (0.04)	-1.17 (0.59)
12	-0.78	-0.80	-0.80	-1.57

PEAK PRESSURE COEFFICIENTS IN EACH SECTION, MODEL B6

Section	Azimuth Angle			
	0	30	60	90
1	-1.11	-1.55	-0.83	-0.94
2	-1.11	-1.32	-0.83	-0.98
3	-0.76	-1.28	-0.96	-0.98
4	-0.76	-1.30	-0.94	-0.94
5	-0.79	-0.91	-0.81	-0.82
6	-0.79	-0.11	0.64	0.76
7	-0.57	-0.13 (0.04)	0.48	0.76
8	-0.57	-0.71	-0.79	-0.82
9	-1.17 (0.76)	-2.85	-1.66	-0.91
10	-1.07 (0.76)	-0.93 (0.82)	-1.06 (0.89)	-1.17 (0.61)
11	-0.78	-1.23	-0.83	-1.15 (0.61)
12	-0.78	-1.17	-1.74	-0.91

PEAK PRESSURE COEFFICIENTS IN EACH SECTION, MODEL C6

Section	Azimuth Angle			
	0	30	60	90
1	-0.96	-1.74	-0.91	-1.54
2	-0.96	-1.42	-1.26	-1.46
3	-0.72	-1.37	-1.12	-1.46
4	-0.72	-1.46	-1.14	-1.54
5	-0.69	-1.02	-0.83	-1.05
6	-0.69	-0.09	0.56	0.90
7	-0.71	-0.29 (0.10)	0.64	0.90
8	-0.71	-0.89	-0.90	-1.05
9	-1.32 (0.76)	-2.56	-2.20	-1.85
10	-1.32 (0.76)	-1.34 (0.94)	-1.63 (0.96)	-1.65 (0.46)
11	-0.74	-1.50	-2.85	-1.65 (0.46)
12	-0.74	-1.27	-0.90	-1.85

PEAK PRESSURE COEFFICIENTS IN EACH SECTION, MODEL D

Section	Azimuth Angle			
	0	30	60	90
1	-1.36	-3.04	-1.23	-0.88
2	-1.36	-2.54	-1.63 (0.04)	-0.60 (0.48)
3	-1.06	-1.32	-1.20	-0.60 (0.48)
4	-1.06	-1.41	-1.34	-0.88
5	-0.78	-0.74	-0.73	-0.78
6	-0.78	-0.39	0.22	0.60
7	-0.58	-0.67	-0.22 (0.28)	0.60
8	-0.58	-0.43	-0.72	-0.78
9	-1.36 (0.38)	-3.04	-1.74	-1.71
10	-1.36 (0.38)	-2.54	-2.11 (0.22)	-1.76 (0.47
11	-1.06	-1.00	-1.08	-1.76 (0.47)
12	-1.06	-1.05	-0.93	-1.71

Appendix D

EXAMPLE WIND LOAD CALCULATIONS

PROBLEM:

Find wind and anchor loads on the center section of a series 50 clamsmeter w/7 bays as a function of velocity. Assume 90-degree azimuth angle.

SOLUTION:

From NAVFAC DM-2.2, wind loads on structures are calculated from,

$$q = 0.00256\ C_h\ Cp\ v^2$$

where: q = load (in lb/ft^2)

C_h = height correction factor (= 1 for h <30 ft)

Cp = pressure coefficient

v = wind velocity (mph)

For the structure under study, the overall dimensions are,

h = 24 ft, peak; (10-ft eave)

d = 61 ft

l = 140.5 ft (87.5-ft center section)

then,

$l/d = 2.30, \quad h/d = 0.39$

from the models tested, model A3 was,

$l/d = 2.26, \quad h/h = 0.38$

The appropriate section average and peak pressure coefficients are found in Appendixes B and C. They are:

Section	Cp	Cp (max)
1. Windward side	0.55	0.57
2. Windward roof	-0.40	-1.11
3. Leeward roof	-1.00	-1.17
4. Leeward side	-0.95	-1.00

Substitution into the wind load equation gives,

Section	q	q (max)
1	$0.0014V^2$	$0.0015V^2$
2	$-0.0010V^2$	$-0.0028V^2$
3	$-0.0026V^2$	$-0.0030V^2$
4	$-0.0026V^2$	$-0.0030V^2$

These are plotted in Figures D-1 and D-2.

The total section loads are found from,

$$f_T = q\ A$$

where f_T = total section load

A = section area

for this structure,

Section	Area (ft^2)	Ft (lbs)
1	894.25	$1.26V^2$
2	2794.75	$-2.86V^2$
3	2794.75	$-7.15V^2$
4	894.25	$-2.17V^2$

These loads are plotted in Figure D-3.

To calculate anchor loads, the section loads per foot of length are given above. These can be resolved to concentrated loads acting at the midpoint of each section, or shown in Figure D-4 (assuming the frame is pinned on the windward side and simply-supported on the leeward side.)

$$\Sigma f_x = 0 = -h_1 + 0.014^2 - 0.0143v^2 + 0.0364v^2 + 0.0240v^2;$$

$$\boxed{h_1 = 0.0601v^2}$$

$$\Sigma F_y = 0 = -v_1 - 0.003v^2 + 0.0294v^2 + 0.0746v^2 + 0.0051v^2 - v_2;$$

$$v_1 + v_2 = 0.1061v^2$$

$$\Sigma M_a = 0 = (0.003)(1.06)v^2 + (0.014)(4.99)v^2 - (0.0143)(17)v^2$$

$$- (0.0294)(16.48)v^2 - (0.0746)(44.52)v^2 + (0.0364)$$

$$(17)v^2 - (0.0051)(5\ .94)v^2 + (0.0240)(4.99)v^2 + 61v_2;$$

$$\boxed{v_2 = 0.0581v}$$

from (2),

$$\boxed{v_1 = 0.0480v^2}$$

On the windward side,

$$v_T = [(0.0480v^2)^2 + (0.0601v^2)^2]^{1/2} = 0.0769v^2$$

The total anchor loads are,

$$v_T \text{ (windward)} = 6.7288v^2$$

$$v_T \text{ (leeward)} = 5.0838v^2$$

These are plotted in Figure D-5.

The total required anchor capacities are plotted in Figure D-6.

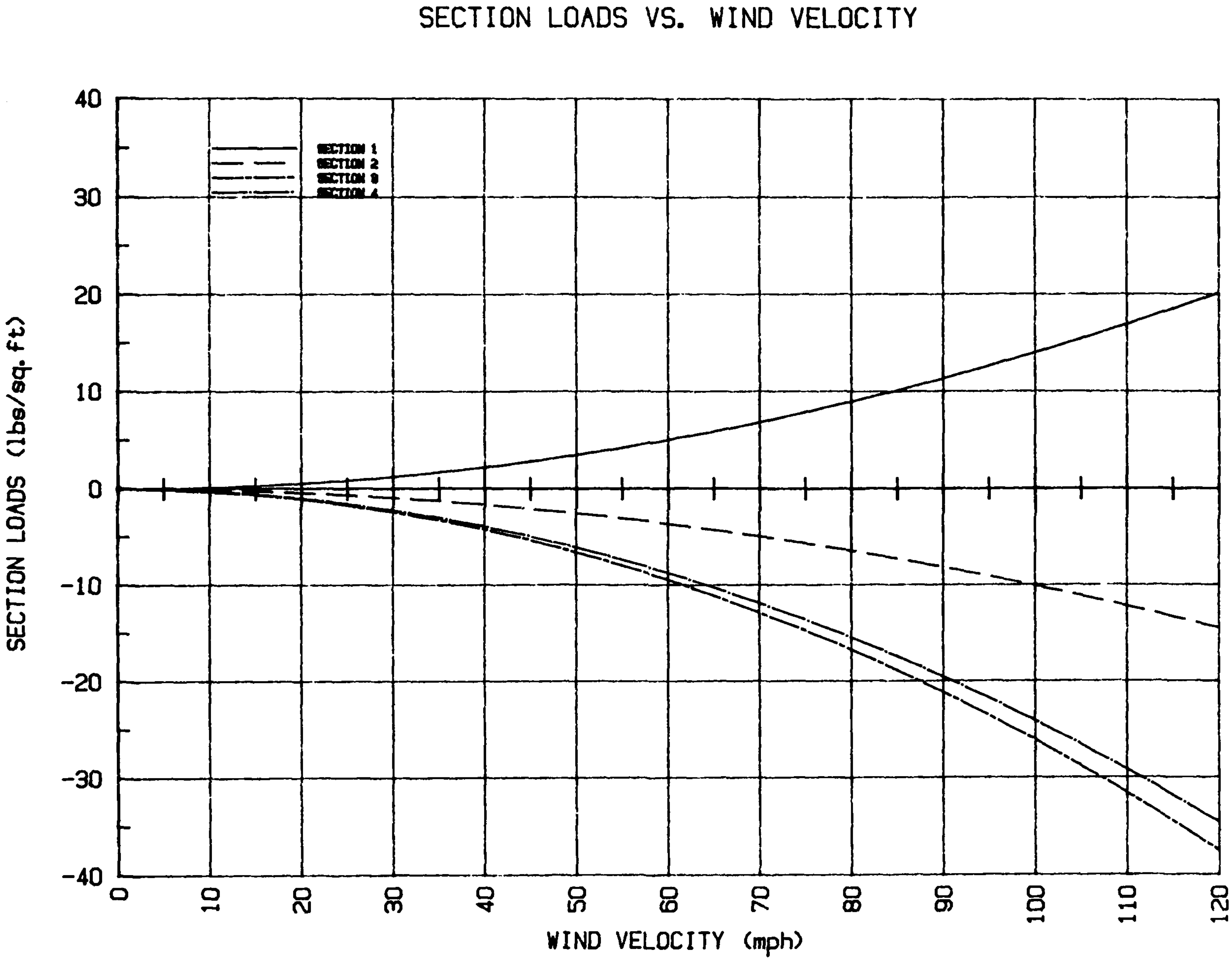


Figure D-1. Section loads versus wind velocity.

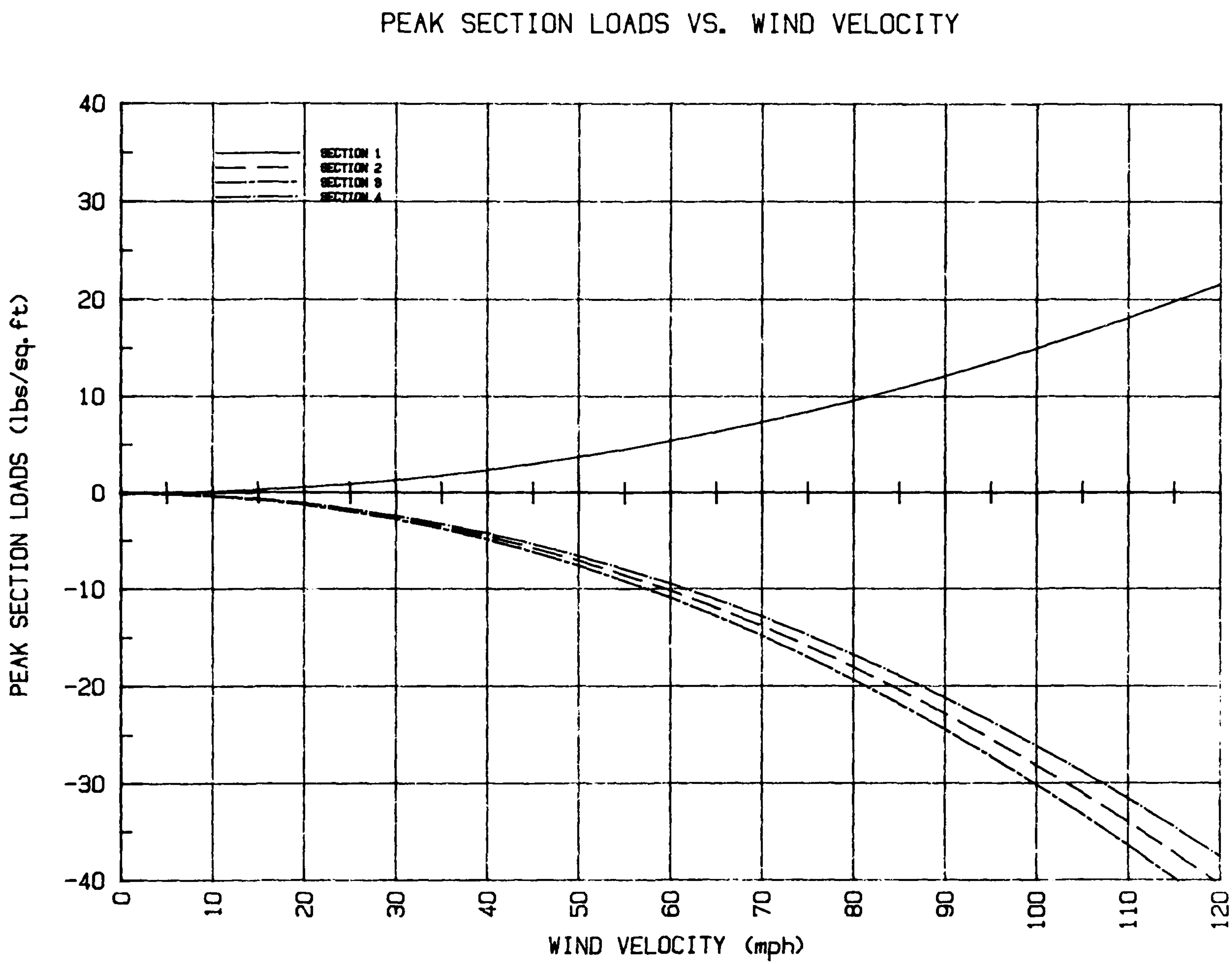


Figure D-2. Peak section loads versus wind velocity.

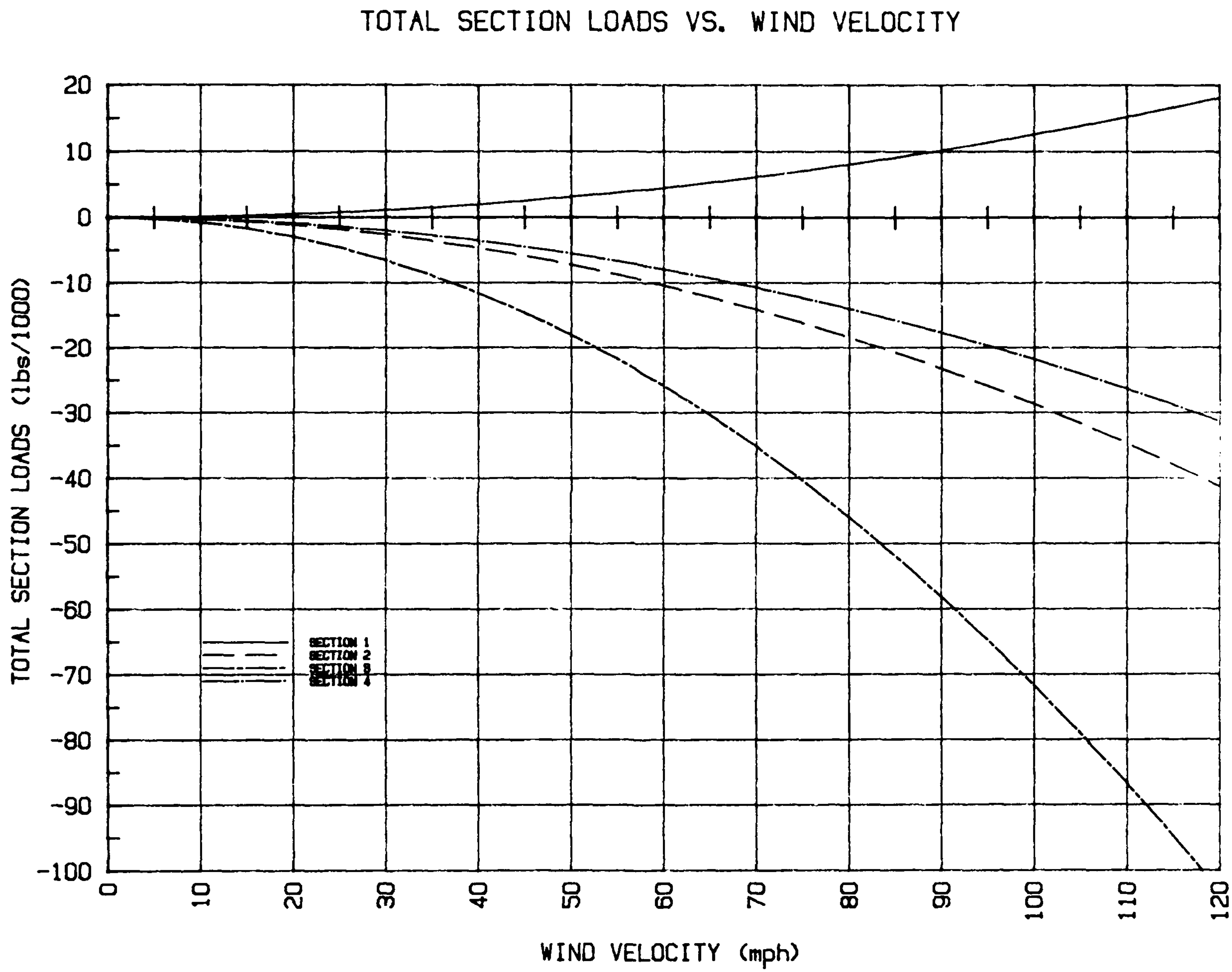


Figure D-3. Total section loads versus wind velocity.

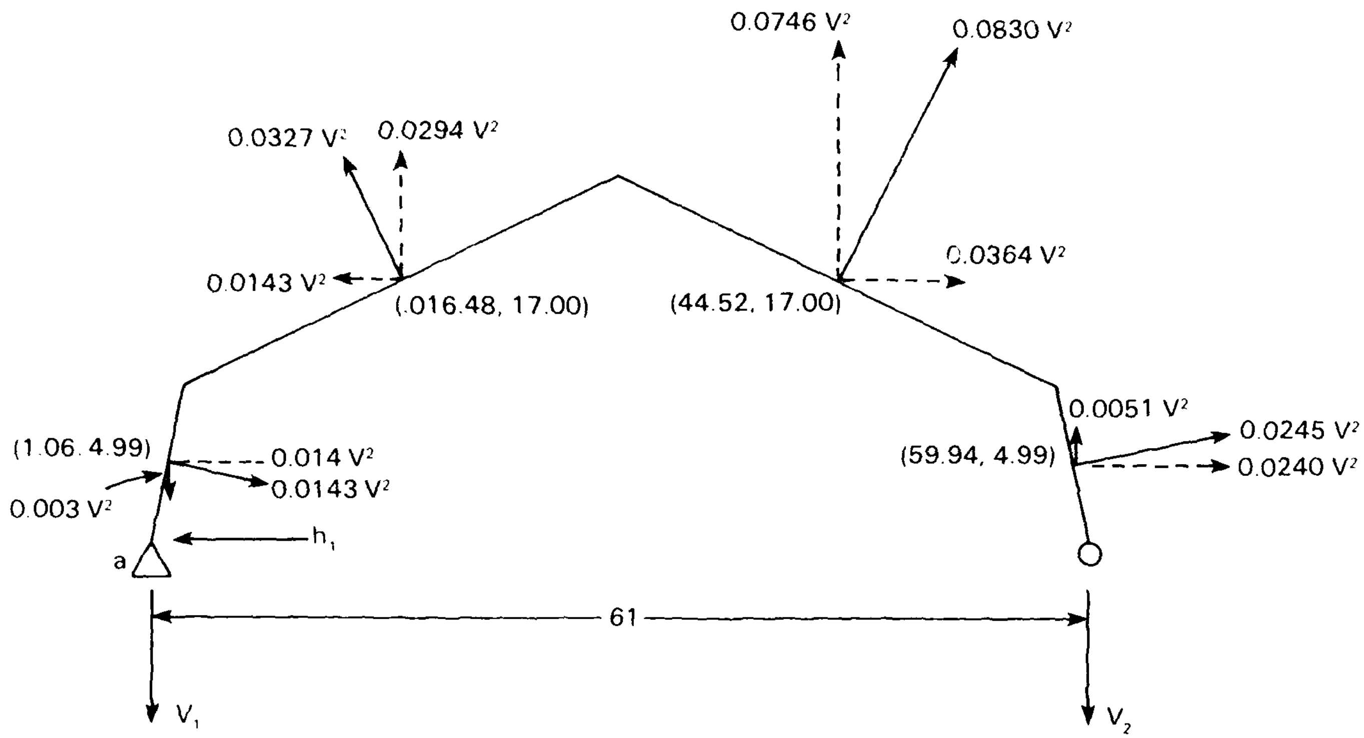


Figure D-4. Load concentrations.

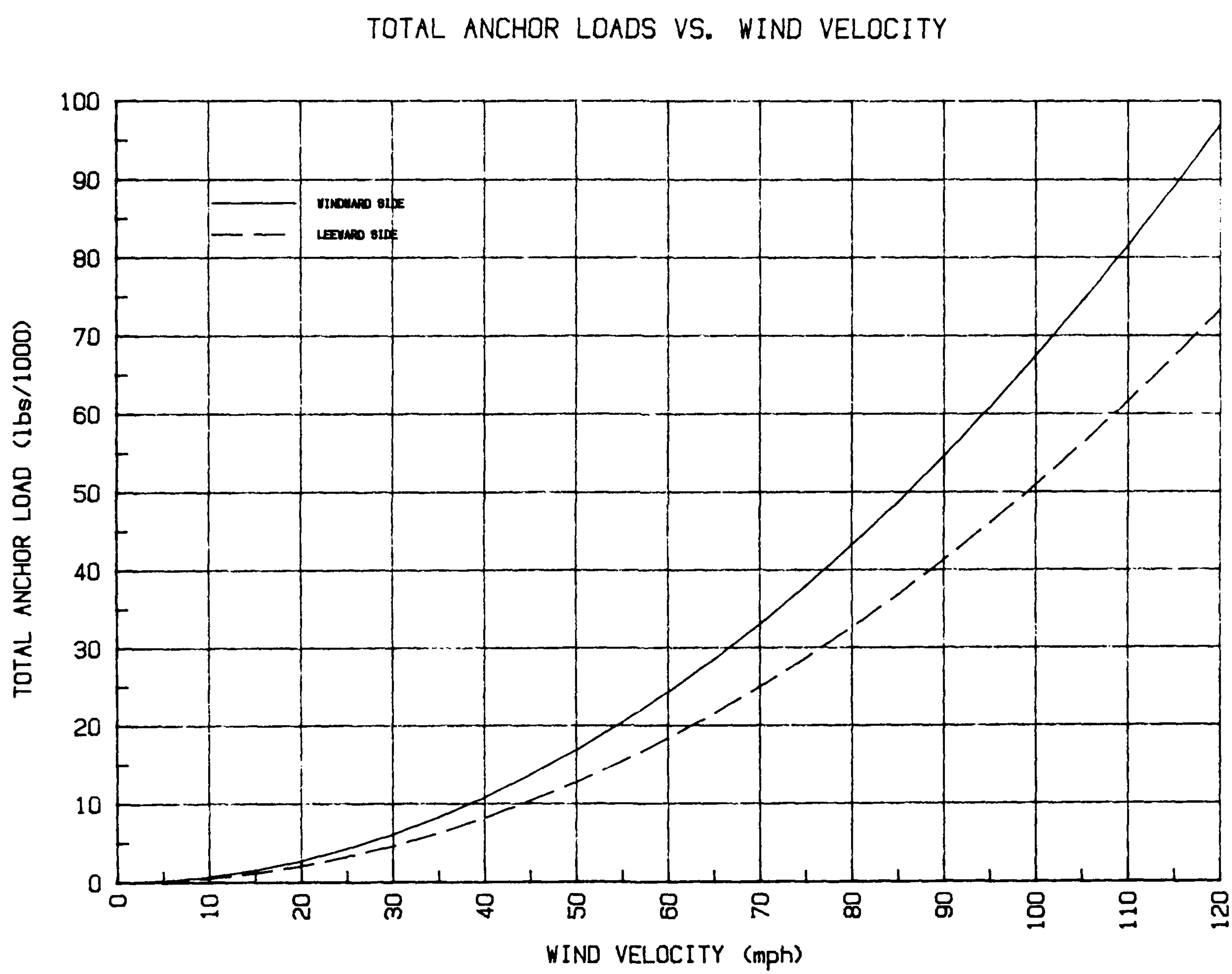


Figure D-5. Total anchor loads versus wind velocity.

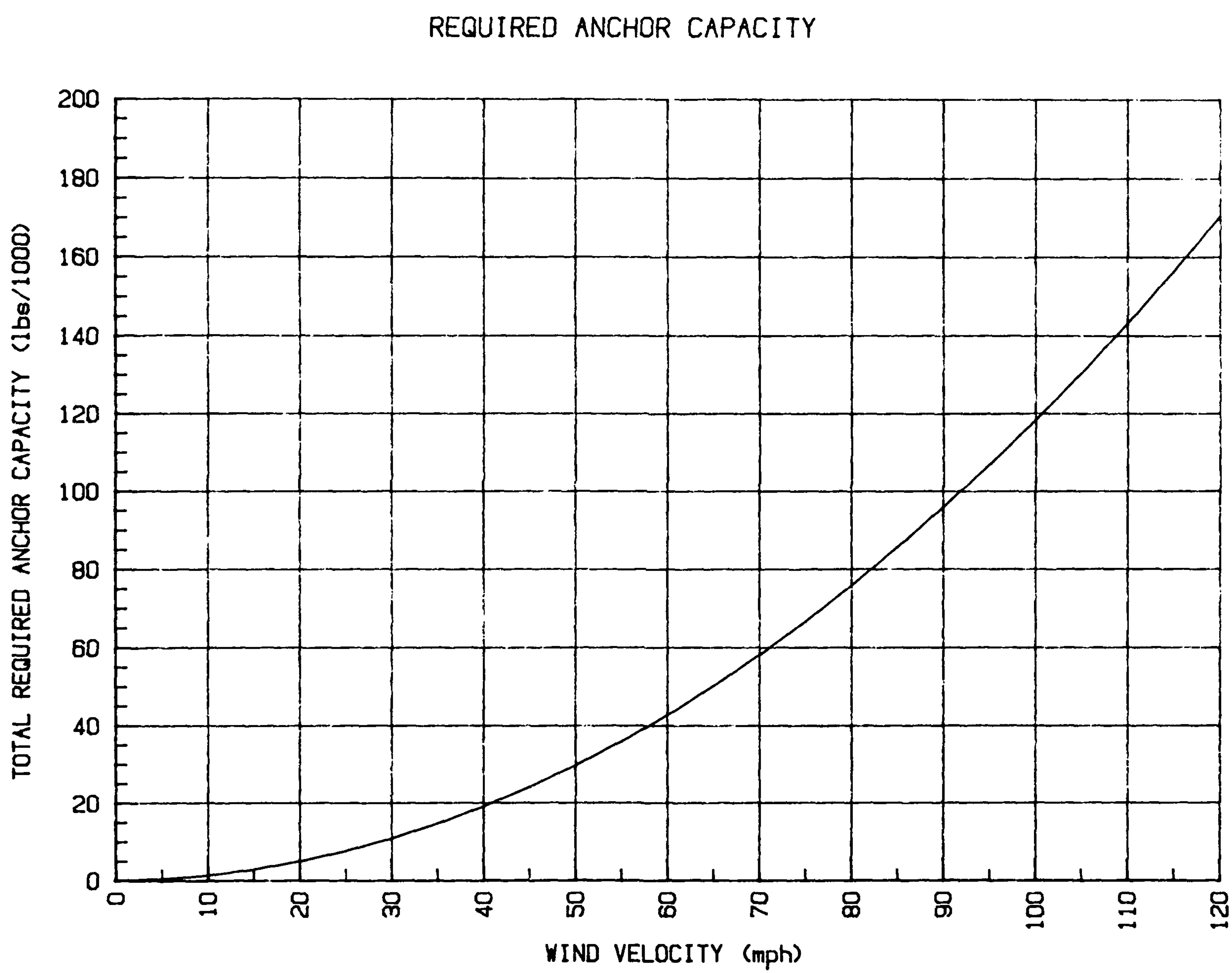


Figure D-6. Required anchor capacity.

INSTRUCTIONS

The Naval Civil Engineering Laboratory has revised its primary distribution lists. The bottom of the label on the reverse side has several numbers listed. These numbers correspond to numbers assigned to the list of Subject Categories. Numbers on the label corresponding to those on the list indicate the subject category and type of documents you are presently receiving. If you are satisfied, throw this card away (or file it for later reference).

If you want to change what you are presently receiving:

- Delete – mark off number on bottom of label.
- Add – circle number on list.
- Remove my name from all your lists – check box on list.
- Change my address – line out incorrect line and write in correction **(DO NOT REMOVE LABEL).**
- Number of copies should be entered after the title of the subject categories you select.

Fold on line below and drop in the mail.

Note: Numbers on label but not listed on questionnaire are for NCEL use only, please ignore them.

Fold on line and staple.

DEPARTMENT OF THE NAVY

Naval Civil Engineering Laboratory
Port Hueneme, CA 93043-5003

Official Business
Penalty for Private Use, $300

NO POSTAGE NECESSARY IF MAILED IN THE UNITED STATES

BUSINESS REPLY CARD
FIRST CLASS PERMIT NO. 69
POSTAGE WILL BE PAID BY ADDRESSE

Commanding Officer
Code L34
Naval Civil Engineering Laboratory
Port Hueneme, California 93043-5003

DISTRIBUTION QUESTIONNAIRE

The Naval Civil Engineering Laboratory is revising its Primary distribution lists.

SUBJECT CATEGORIES

1 SHORE FACILITIES
2 Construction methods and materials (including corrosion control, coatings)
3 Waterfront structures (maintenance/deterioration control)
4 Utilities (including power conditioning)
5 Explosives safety
6 Aviation Engineering Test Facilities
7 Fire prevention and control
8 Antenna technology
9 Structural analysis and design (including numerical and computer techniques)
10 Protective construction (including hardened shelters, shock and vibration studies)
11 Soil/rock mechanics
14 Airfields and pavements

15 ADVANCED BASE AND AMPHIBIOUS FACILITIES
16 Base facilities (including shelters, power generation, water supplies)
17 Expedient roads/airfields/bridges
18 Amphibious operations (including breakwaters, wave forces)
19 Over-the-Beach operations (including containerization, materiel transfer, lighterage and cranes)
20 POL storage, transfer and distribution

28 ENERGY/POWER GENERATION
29 Thermal conservation (thermal engineering of buildings, HVAC systems, energy loss measurement, power generation)
30 Controls and electrical conservation (electrical systems, energy monitoring and control systems)
31 Fuel flexibility (liquid fuels, coal utilization, energy from solid waste)
32 Alternate energy source (geothermal power, photovoltaic power systems, solar systems, wind systems, energy storage systems)
33 Site data and systems integration (energy resource data, energy consumption data, integrating energy systems)

34 ENVIRONMENTAL PROTECTION
35 Solid waste management
36 Hazardous/toxic materials management
37 Waste water management and sanitary engineering
38 Oil pollution removal and recovery
39 Air pollution

44 OCEAN ENGINEERING
45 Seafloor soils and foundations
46 Seafloor construction systems and operations (including diver and manipulator tools)
47 Undersea structures and materials
48 Anchors and moorings
49 Undersea power systems, electromechanical cables, and connectors
50 Pressure vessel facilities
51 Physical environment (including site surveying)
52 Ocean-based concrete structures
54 Undersea cable dynamics

TYPES OF DOCUMENTS

85 Techdata Sheets
86 Technical Reports and Technical Notes
83 Table of Contents & Index to TDS
82 NCEL Guides& Abstracts
91 Physical Security
☐ None– remove my name

DISTRIBUTION LIST

AF AFIT DET. Wright-Patterson AFB. OH
AF HQ ESD AVMS. Hanscom AFB. MA; LETT (Cargo). Washington. DC
AFB 42 CES DEMU (Drechsel). Loring AFB. ME
AFESC TST (Library). Tyndall AFB. FL
ARMY Ch of Engrs. DAEN-MPU. Washington. DC; HQDA (DAEN-ZCM). Washington. DC; R&D Cmd. STRNC-US (J Siegel). Natick. MA
ARMY BELVOIR R&D CEN STRBE-AALO. Ft Belvoir. VA; STRBE-BLORE. Ft Belvoir. VA; STRBE-FS. Ft Belvoir. VA
ARMY CERL CECER-EME (Hayes). Champaign. IL; CERL-ZN. Champaign. IL; Library. Champaign. IL
ARMY CORPS OF ENGRS A. Azares. Sacramento. CA
ARMY EHA HSHB-EW. Aberdeen Proving Grnd. MD
ARMY EWES GP-EC (Webster). Viesburg. MS; Library. Vicksburg MS; WESGP-E. Vicksburg. MS
ARMY LOGC ALC ATCL-MS (Morrissett). Fort Lee. VA
ARMY TRANS SCH ASTP-CDM. Fort Eustis. VA
CBC Library. Davisville. RI; Tech Library. Gulfport. MS
CINCLANTFLT CE Supp Plans Offr. Norfolk. VA
CINCPACFLT Code 442. Pearl Harbor. HI
CNA Tech Library. Alexandria. VA
CNO DCNO. Logs. OP-424C. Washington. DC
COMDT COGARD Library. Washington. DC
COMFAIR SEC. Naples. Italy
COMNAVAIRSYSCOM Code 41712A. Washington. DC; Code 422. Washington. DC
DIA DB-6E1. Washington. DC
DTIC Alexandria. VA
DTRCEN Code 1250. Annapolis. MD; DET. Code 4120. Annapolis. MD
FAA Code APM-740 (Tomita). Washington. DC
FMFPAC SCIAD (G5). Camp HM Smith. HI
GIDEP OIC. Corona. CA
LIBRARY OF CONGRESS Sci & Tech Div. Washington. DC
MCAF Code C144. Quantico. VA
MCRDAC M & L Div Quantico. VA; NSAP Rep. Quantico. VA
NAS Code 83. Patuxent River. MD
NAVAIRDEVCEN Code 8323. Warminster. PA
NAVAIRENGCEN PWO. Lakehurst. NJ
NAVAIRTESTCEN PWO. Patuxent River. MD
NAVCOASTSYSCEN Code 2360. Panama City. FL; Tech Library. Panama City. FL
NAVFACENGCOM Code 00. Alexandria. VA; Code 03. Alexandria. VA; Code 03T (Essoglou). Alexandria. VA; Code 04A. Alexandria. VA; Code 04A3. Alexandria. VA; Code 04A3C. Alexandria. VA; Code 06. Alexandria. VA; Code 0631. Alexandria. VA; Code 09M124 (Lib). Alexandria. VA
NAVFACENGCOM - CHES DIV. FPO-1PL. Washington. DC
NAVFACENGCOM - LANT DIV. Br Ofc. Dir. Naples. Italy; Code 1112. Norfolk. VA; Code 405. Norfolk. VA; Library. Norfolk. VA
NAVFACENGCOM - NORTH DIV. Code 04AL. Philadelphia. PA; Code 11. Philadelphia. PA
NAVFACENGCOM - PAC DIV. Code 09P. Pearl Harbor. HI; Code 2011. Pearl Harbor. HI; Library. Pearl Harbor. HI
NAVFACENGCOM - SOUTH DIV. Code 1112. Charleston. SC; Code 406. Charleston. SC; Library. Charleston. SC
NAVFACENGCOM - WEST DIV. 09P.20. San Bruno. CA; Code 04A2.2 (Lib). San Bruno. CA; Code 04B. San Bruno. CA; Code 09B. San Bruno. CA; Code 408.2 (Jeung) San Bruno. CA
NAVSCOLCECOFF Code C35. Port Hueneme. CA
NAVSWC Code E211 (Miller). Dahlgren. VA; Code G-34. Dahlgren. VA. DET. White Oak Lab. Code H-101. Silver Spring. MD; PWO. Dahlgren. VA
NAVWARCOL Code 24. Newport. RI
NAVWPNCEN AROICC. China Lake. CA; Code 2637. China Lake. CA
NETC PWO. Newport. RI
NEESA Code 111E (McClaine). Port Hueneme. CA; Code 113M. Port Hueneme. CA
NMCB 74. CO
NRL Code 2511. Washington. DC
NUSC DET Code 3232 (Varley). New London. CT
OFFICE OF SECRETARY OF DEFENSE OASD (P&L). M. Carr. Washington. DC
PWC Code 101 (Library). Oakland. CA; Code 123-C. San Diego. CA; Code 420. Great Lakes. IL; Library (Code 134). Pearl Harbor. HI; Library. Guam. Mariana Islands; Library. Norfolk. VA; Library. Pensacola. FL; Library. Yokosuka. Japan; Tech Library. Subic Bay. RP
US DEPT OF INTERIOR Natl Park Svc. RMR PC. Denver. CO

USDA For Svc Reg 8, (Bowers), Atlanta, GA; For Svc, Tech Engrs, Washington, DC
USNA Ocean Engrg Dept (McCormick), Annapolis, MD; Sys Engrg, Annapolis, MD
CITY OF AUSTIN Gen Svcs Dept (Arnold), Austin, TX
CITY OF BERKELEY PW, Engr Div (Harrison), Berkeley, CA
LEHIGH UNIVERSITY Linderman Library, Bethlehem, PA
MIT Engrg Lib, Cambridge, MA; Lib, Tech Reports, Cambridge, MA
NATL ACADEMY OF SCIENCES NRC, Dr. Chung, Washington, DC; NRC, Naval Studies Bd, Washington, DC
PURDUE UNIVERSITY Engrg Lib, W. Lafayette, IN
SOUTHWEST RSCH INST Energetic Sys Dept (Esparza), San Antonio, TX
SRI INTL J.L. Jones, Chem Engr Lab, Menlo Park, CA
TECH UTILIZATION K Willinger, Washington, DC
UNIVERSITY OF ILLINOIS Arch Scol (Kim), Champaign, IL; Metz Ref Rm, Urbana, IL
UNIVERSITY OF NEBRASKA Polar Ice Coring Office, Lincoln, NE
UNIVERSITY OF NEW MEXICO NMERI (Leigh), Albuquerque, NM
UNIVERSITY OF TEXAS Construction Industry Inst, Austin, TX
WASHINGTON DHHS, OFE PHS (Ishihara), Seattle, WA
APPLIED SYSTEMS R. Smith, Agana, Guam
ARVID GRANT & ASSOC Olympia, WA
ATLANTIC RICHFIELD CO RE Smith, Dallas, TX
AWWA RSCH FOUNDATION R. Heaton, Denver, CO
BATTELLE D Frink, Columbus, OH
BECHTEL CIVIL, INC Woolston, San Francisco, CA
CONSTRUCTION TECH LABS, INC G. Corley, Skokie, IL
DURLACH, O'NEAL, JENKINS & ASSOC Columbia, SC
ENERCOMP H. Amistadi, Brunswick, ME
GDM & ASSOC, INC Fairbanks, AK
INTL MARITIME, INC D Walsh, San Pedro, CA
IRE-ITTD Input Proc Dir (R. Danford), Eagan, MN
LAYTON & SELL, INC, P.S. Mfg Rsch Dept (Edwards), Marietta, GA
LEO A DALY CO Honolulu, HI
LINDA HALL LIBRARY Doc Dept, Kansas City, MO
NATL ACADEMY OF ENGRG Alexandria, VA
TANDEMLOC, INC J DiMartino, Jr, Ronkonkoma, NY
WELLSPRING COMM H Zarecor, Marshall, VA
BULLOCK, TE La Canada, CA
PADILLA, LM Oxnard, CA
PETERSEN, CAPT N.W. Pleasanton, CA
QUIRK, J Panama City, FL
STEVENS, TW Long Beach, MS
ULASZEWSKI, CDR T.J. Honolulu, HI